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PART I: BOTANY AND FORESTRY

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VOLUME XXIX (1943)
PART I: BOTANY AND FORESTRY

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
— SENECA, *Naturales Quaestiones*

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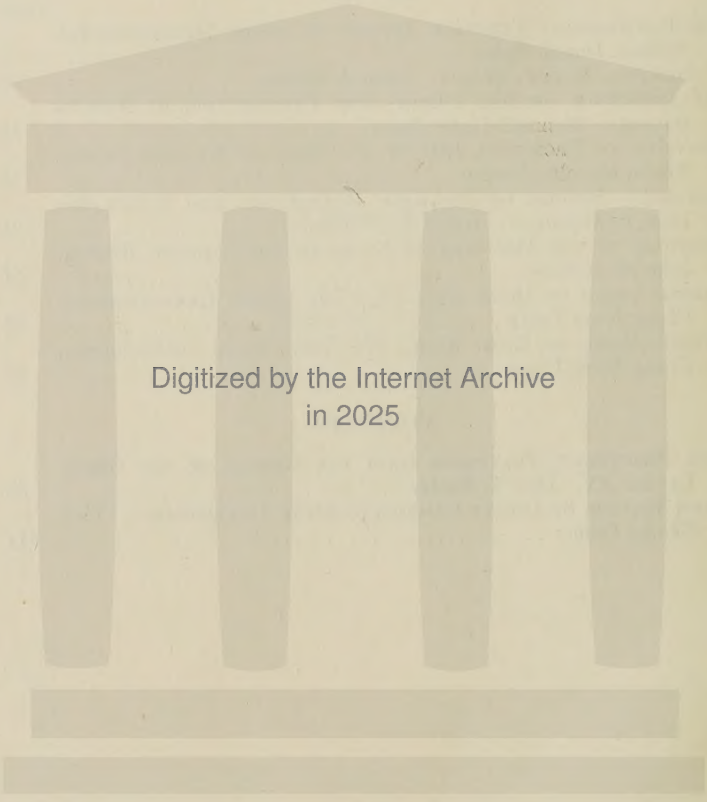

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BOTANY

THE DISCRIMINANT FUNCTION APPLIED TO SPORE MEASUREMENTS *

WILLIAM DOWELL BATEN

INTRODUCTION

LENGTH and width measurements of spores of *Galera crispa* and *Galera lactea*, which grow side by side on the campus of Michigan State College, were made by Bessey (1) in order to determine whether or not there were significant differences in arithmetic averages of spore dimensions pertaining to these species of fungi. Measurements of 140 spores from four specimens of the former and of 160 spores from four specimens of the latter were made. An analysis of variance was carried out on the length and width measurements of each species to determine homogeneity among length and width averages pertaining to specimens; these analyses revealed no evidence of heterogeneity.

There are several methods of finding significant differences between the averages of these measurements. One is to test for significance between means of length measurements and then to make a similar test between means of width measurements.

99 PER CENT ELLIPSES

One of the methods used in this paper is that of inquiring into the significance between the points $(\bar{x}, \bar{y})$ and $(\bar{x}', \bar{y}')$ in a plane (where $\bar{x}$ and $\bar{y}$ represent respectively the means of length and width measurements of *Galera crispa* spores and $\bar{x}'$ and $\bar{y}'$ represent respectively means of similar spore measurements of *Galera lactea*). These points are (12.26, 8.21) and (12.15, 7.49); they are plotted in Figure 1, together with their 99 percentage ellipses. Rietz (6) shows how these ellipses can be obtained. Since they do not overlap, the centers are significantly separated, and hence the arithmetic averages of lengths and widths taken together for one species are significantly different

* Authorized as journal article No. 632, N. S., of the Michigan Agricultural Experiment Station.

from those of the other species. This indicates that spores of *Galera crispa* are definitely larger than those of *Galera lactea*. The interpretation of this test is that, if many samples of 140 spores of *Galera crispa* are taken at random from the parent population, on the average

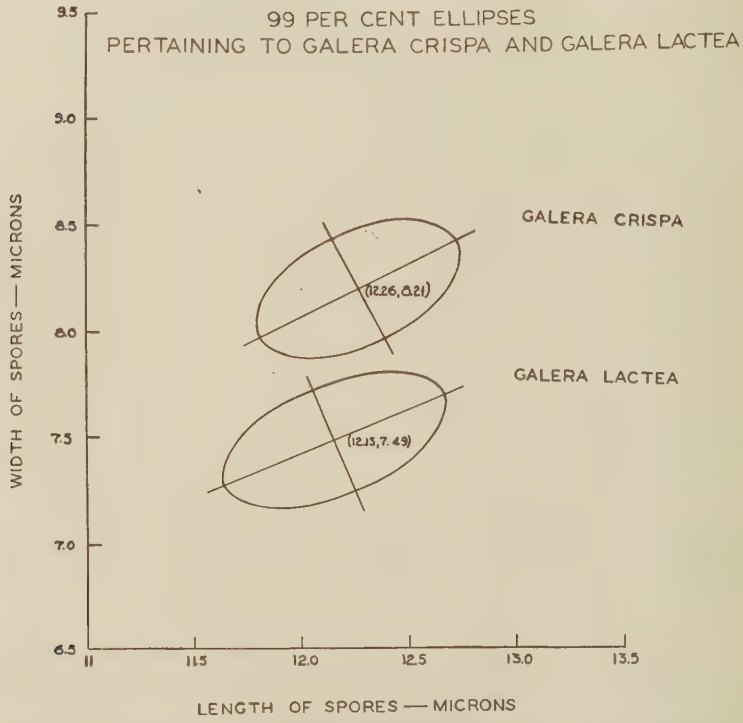

Fig. 1. Ninety-nine per cent ellipses pertaining to averages of length and width measurements of spores of *Galera crispa* and *Galera lactea*

about 99 per cent of the points (one point determined from each sample) will fall within this ellipse; and since these points fall about the point representing the true means of length and width measurements, the odds are 99 to 1 that the point representing the true means will fall in this ellipse, or 1 to 99 that it will fall on the outside. The same interpretation can be given to the point representing the true averages pertaining to the other species. If this is true, it is clear

that points representing the true parent universes (*Galera crispa* and *Galera lactea*) are statistically separated or that these two species differ in averages pertaining to spore measurements.

THE DISCRIMINANT FUNCTION

Let a linear compound made up of spore length and spore width be $X = ax + by$, where x and y represent respectively length and width of *Galera crispa* spores and a and b are constants to be found. Let the linear compound pertaining to the other species be $X' = ax' + by'$. The two functions X and X' have the same a and b constants. Let the difference between the means of these be represented by

$$D = ad_1 + bd_2,$$

where $d_1 = \bar{x} - \bar{x}'$ and $d_2 = \bar{y} - \bar{y}'$. Let

$$\begin{aligned} S = a^2[\Sigma(x - \bar{x})^2 + \Sigma(x' - \bar{x}')^2] \\ + 2ab[\Sigma(x - \bar{x})(y - \bar{y}) + \Sigma(x' - \bar{x}')(y' - \bar{y}')] \\ + b^2[\Sigma(y - \bar{y})^2 - \Sigma(y' - \bar{y}')^2], \end{aligned}$$

or the sum of squares of the compounds *within species*. A linear function composed of length and width measurements is desired which will discriminate the most between these species or a linear function among all possible linear functions that will show the most difference between these species. This one compound or discriminant function is found by maximizing the ratio D^2/S. On maximizing this ratio the following simultaneous equations are obtained,

$$[\Sigma(x-\bar{x})^2+\Sigma(x'-\bar{x}')^2]a+[\Sigma(x-\bar{x})(y-\bar{y})+\Sigma(x'-\bar{x}')(y'-\bar{y}')]b=d_1,$$
$$[\Sigma(x-\bar{x})(y-\bar{y})+\Sigma(x'-\bar{x}')(y'-\bar{y}')]a+[\Sigma(y-\bar{y})^2+\Sigma(y'-\bar{y}')^2]b=d_2,$$

from which the values of a and b are derived. From the data these equations are

$$\begin{aligned} 789.06a + 246.59b &= 0.11, \\ 246.59a + 290.59b &= 0.72, \end{aligned}$$

from which $a = -0.000863$ and $b = 0.003210$. The compound X is

$$X = -0.000863x + 0.003210y.$$

This discriminant function enables one to evaluate a combination of length and width measurements of spores. It furnishes a measure for comparing compounds made up of length and width measure-

ments of spores from the two species. The difference between the means of the compounds pertaining to the two species is

$$(1)\quad D = -0.000863(0.11) + 0.003210(0.72)$$
$$= -0.000949 + 0.002311 = 0.002216.$$

The following table, containing an analysis of variance of the two discriminant functions, shows that there is a significant difference between the arithmetic averages of these linear compounds. This indicates that the discriminant function pertaining to one species is significantly different from the discriminant function made up of length and width of spores pertaining to the other.

TABLE I

ANALYSIS OF VARIANCE PERTAINING TO THE DISCRIMINANT FUNCTIONS

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	299	$D\left[1 + \frac{N_1 \cdot N_2}{N_1 + N_2} D\right] = 0.002583$	
Between species means	2	$\frac{N_1 \cdot N_2}{N_1 + N_2} D^2 = 0.000367$	0.000184*
Within species	297	$D = 0.002216$	0.000007

* Significant at the 1 per cent point.

On examining the numerical value of D in formula (1) it is seen that the difference between the averages of widths multiplied by b is larger than the difference between the averages of length measurements multiplied by a; hence width measurements are more important than length measurements for determining significance between these species.

The discriminant function can be used in comparing two linear combinations of several variables. Its coefficients furnish weights (if written in standard units) to the quantities measured. Literature pertaining to this function can be found in references 2–5.

SUMMARY

Three methods have been presented for testing significance between means pertaining to length and width measurements of spores

from two species of fungi. Special attention was given to the 99 percentage ellipses and to R. A. Fisher's discriminant function (5). The discriminant function enables one to test for a difference between two linear compounds of measurements under consideration.

I am grateful to Dean E. A. Bessey for supplying the data for this study.

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STUDIES UPON *GALERA CRISPA*

ERNST A. BESSEY

IN 1899 Burton O. Longyear (5) described as new, under the name *Galera crispa*, a small mushroom that had been collected in the vicinity of Michigan Agricultural College (now Michigan State College) for a number of years. It is still abundant in the same locality and is reported by Kauffman (2) at Ann Arbor and other points in the Lower Peninsula of Michigan. According to Hard (1), it was observed by Longyear in Denver, Colorado, in 1905. It is a sod-inhabiting fungus, mostly growing in lawns or pastures of Kentucky bluegrass (*Poa pratensis* L.) and of Bermuda grass (*Cynodon dactylon* (L.) Pers.) where there is little or no shade. The little mushrooms appear from mid-July to early September two to four days after a heavy rain or a period of gentle showers. They push up during the night and last but a few hours if the day is sunny. The elements of the gills, like those of the closely related species *Bolbitius tener* Berk., soon begin to dissolve and disintegrate, but they do so much more slowly. Between ten and twelve o'clock on a warm day the details of the structure of the trama, basidia, cystidia, and other parts cannot be made out.

Often intermingled with *G. crispa* in Michigan, and usually more abundant, is a species that has been confused by Kauffman (2), Hard (1), and other American botanists as well as by some of the European authors with *G. tenera* (Fr.) Karst. Specimens collected at Las Cruces, New Mexico, early in September, 1942, and sent to me by Dr. Horace L. Barnett agree in all essential particulars with this fungus. In the Herbarium of the Department of Botany of Michigan State College some collections made prior to 1899 are labeled "*G. lateritia* (Fr.) Karst" and others "*G. tenera.*" That there is a whole series of closely similar forms that perhaps constitute a *G. tenera* complex is likely. There is need for an intensive study of all the species, varieties, and forms of this assemblage that have been distinguished in part and given names by Kühner (3), Lange (4), and others. Until this has been done it seems best to call this common

species of central Michigan, not *G. tenera* or *G. lateritia*, but *G. lactea* Lange. The chief distinction between the last two lies in the color. *Galera lateritia*, according to Lange and Kühner, is more or less tile red (as indicated by the specific name), and the bulbous enlargement at the base of the stipe is 6 to 10 mm. in diameter, whereas in *G. lactea* the color is cream white and the bulb is small and rounded. In both of these the tenpin-shaped cheilocystidia are abundant along the edges of the gills, and similar cells are absent or almost so from the stipe. In *G. tenera* the stipe is covered with very numerous structures of this type, and the pileus and stipe are ocher to cinnamon-colored when fresh. The common Michigan species, which I tentatively call *G. lactea*, has a smooth pileus with only a very few long hairs similar to those occurring on the stipe. Kühner says that hairs of this type are abundant on the pileus of *G. lateritia* as he interprets it. The latter, moreover, is mostly larger than the Michigan fungus.

Galera crispa and *G. lactea* are alike in the color of the freshly picked specimens, which is as follows: pileus ivory yellow,[1] with a central chamois spot that varies in size; stipe pure white or almost so for the greater part of its length, becoming ivory yellow near the base. The bulbous enlargement is usually buried in the ground and is more often pure white. On drying all parts become darker, the pileus and stipe uniformly chamois or honey yellow. Fresh specimens show striations from the margin halfway or two thirds the distance to the center of the pileus. On dry specimens these are more accentuated and extend nearly to the center. The fresh stipe is usually minutely striate, but sometimes this condition is not apparent. The surface of the stipe is nearly smooth, but dotted with numerous patches of various size, from 30 to 100 μ in diameter or even larger, which consist of more or less crowded lanceolate hairs 5 to 8 μ thick and about 30 μ long. A varying number of these hairs extend as slender, flexuous hyphae 2.2 to 3.3 μ thick and 36 to 108 μ long. Sometimes these slender hairs lack the lanceolate base. In many of the patches only the lanceolate hairs are present. In only one out of 225 such patches examined were found capitate hairs resembling the tenpin-shaped cheilocystidia of the gills, and it had only a few. The narrowly hollow stipe is slender and nearly or quite straight, enlarging very gradually from the apex to the base, where it forms

[1] Color based on R. Ridgway, *Color Standards and Color Nomenclature*. Washington, 1912.

TABLE I

COMPARATIVE DATA ON DIMENSIONS OF *GALERA CRISPA* AND *G. LACTEA*

	Galera crispa	*Galera lactea*
Height, overall	4.3 – 8.0 cm.	4.0 – 8.4 cm.
Pileus		
Height	8.0 – 12.0 mm.	8.0 – 16.0 mm.
Breadth	10.0 – 21.0 mm.	10.0 – 25.0 mm.
Stipe diameter		
Near top	1.0 – 1.7 mm.	1.0 – 2.0 mm.
Bulb	2.0 – 3.5 mm.	2.5 – 5.0 mm.
Basidia	19.0–30.0 × 7.0–12.0 μ	19.0–29.0 × 9.6–12.0
Basidiospores		
Range	7.2–20.2 × 5.8–12.7 μ	8.6–17.5 × 5.8–10.3 μ
Mean	12.65 × 8.8 μ	12.2 × 7.7 μ
Standard deviation		
Length	2.01 μ	1.98 μ
Breadth	1.33 μ	0.94 μ
Coefficient of correlation of length and breadth	0.62	0.554
Cheilocystidia		
Height	20.0 – 30.0 μ	19.0 – 29.0 μ
Diameter of body	7.0 – 11.0 μ	9.6 – 12.0 μ
Diameter of head	3.0 – 4.6 μ	2.9 – 4.6 μ
Percentage of basidia		
4-spored	54	80–95
3-spored	31	5–20
2-spored	15	

a bulbous swelling. This bulb may be a gradual swelling or may be abrupt, with a distinct margin.

The surface of the pileus is "hymeniform," that is, covered with a palisade of pyriform or clavate cells. This structure is characteristic of the genus Conocybe as delimited by Kühner (treated as a subgenus by Lange). The gills are light-colored, but very soon the maturing basidiospores give them a dark-brown color. The basidia are somewhat pyriform and densely and finely granular at first, scattered among larger sterile hyaline cells two to three times the diameter of the basidia. At the edge of the gill are numerous capitate cheilocystidia shaped like tenpins. They are not evenly distributed but occur in groups of from two or three up to six or eight. The gills are narrow and only slightly attached at the summit of the stipe. The typical spore, which is dark ocher, is more rounded at one end

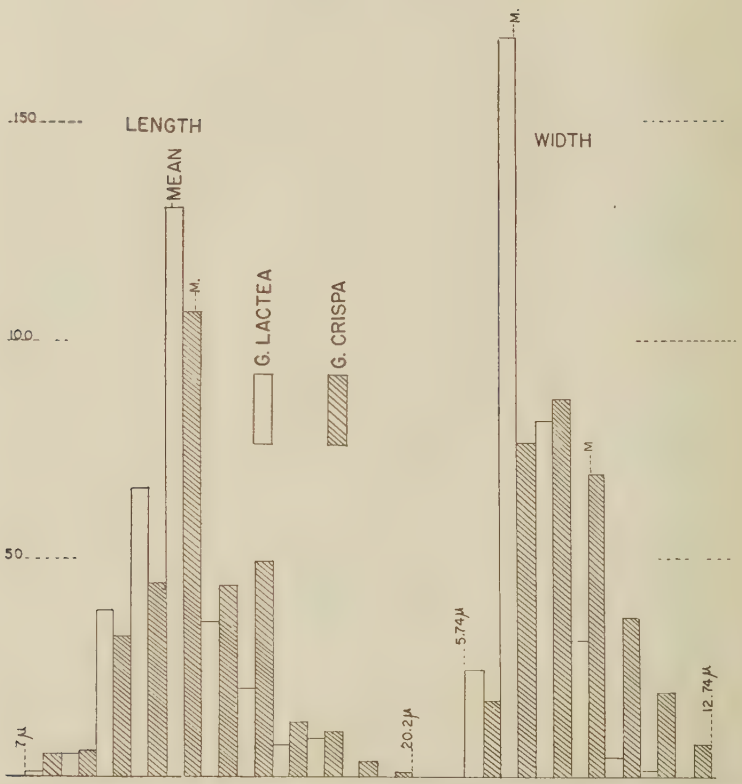

FIG. 1. Distribution of 310 basidiospores in each of the two species, *Galera lactea* and *G. crispa*, by length and width classes. The length classes have a range of 1.2 μ; for the width classes the range is 1.0 μ. In each class the rectangles representing the number of spores of the two species are placed side by side.

and obliquely apiculate at the other end, by which it is attached to the sterigma.

The differences between the two species lie in the shape of the mature pileus, the form of the gills, the number of basidiospores to a basidium, and the variation in the size of the spores. In *G. crispa* the line of attachment of each gill to the pileus is wavy, whereas in *G. lactea* it is straight; in the former the free edges of the gills are more or less crisped, in the latter not at all except occasionally in the

more mature specimens. The main gills of *G. crispa* are connected by numerous transverse and oblique narrow anastomoses, but these are lacking in *G. lactea*. The crisping of the gills indicates the occurrence of considerable elongation of their free edges, the pilear tissue failing to elongate correspondingly, so that an outward curvature is brought about resulting in a campanulate shape in *G. crispa* in contrast to the oval form in *G. lactea*.

In *G. crispa* over 40 per cent of the basidia bear but two or three spores, but 80 to 95 per cent (varying in different hymenophores) are four-spored in *G. lactea*. Frequently basidia occur in the former with four sterigmata developed, one bearing a spore of maximum size, to either side of which the spores appear normal but small, whereas opposite the large spore is a colorless or only slightly colored spore, obviously incapable of development. Attempts were made to study the nuclear behavior of the basidia in both species, but apparently the material was fixed too late in the morning, so that disintegration of the tissues had already begun.

The spores of *G. crispa* are more variable in size and of greater range of dimensions than those of *G. lactea*. Through the kindness of Dr. W. D. Baten, of Michigan State College, a comparative statistical study was made of the spore sizes. The results will be presented in a separate paper by Dr. Baten (see pp. 3–7).

In Table I are given the comparative dimensions of the various structures of the two species. In Figure 1 is shown in the form of a histogram the distribution of the basidiospores by size classes.

Drawing conclusions from the foregoing data I am inclined to believe that *Galera crispa* represents a mutation from *G. lactea*, perhaps one that has occurred at various times and places. Attempts were made, unsuccessfully, by one of my graduate students, John B. Routien, to bring both of these species into culture with the intention of making crosses between them for the purpose of genetic studies that might throw light on the problem.

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THE INFLUENCE OF SOIL DEPTH UPON DISTRIBUTION OF ACTINOMYCETES*

KENNETH LESTER JONES

DURING the past five years the author has made from time to time plate counts of actinomycetes from soils in the vicinity of Ann Arbor, Michigan. Most samples were taken from the surface, but the numerous excavations for "defense houses" made convenient the collection of others from freshly exposed subsoil.

The samples were collected and either plated at once or stored at 5° C. and plated within a few days. In preparing the dilutions a fifty-gram sample was suspended in 500 c.c. sterile tap water, and the dilution series were made from 10 c.c. portions of suspension in 90 c.c. water blanks. Ordinarily the 1 : 10,000 or 1 : 100,000 dilutions were employed as inocula, although in the subsoil the organisms were so few that even a 1 : 10 dilution was too high. A medium used by Jensen (1930) proved very successful. Ten replicate plates of each dilution were poured. The cultures were incubated at 28° C. for two weeks, and counts were then tabulated from observations under a wide field binocular (20 ×). Doubtful colonies were observed under a magnification of 44 diameters.

Table I gives the "counts" of actinomycetes in various surface soils stated in millions per gram of dry soil. It also gives the pH of the soil, the water content, and the percentage of actinomycetes compared with the total number of bacteria and actinomycetes.

The "number" of actinomycetes in a gram of dry soil ranged from 100,000 to 25,400,000, and the percentage from 2 to 70. The grassland soils had a count of 5.6–25.4 millions, with 21–57 per cent actinomycetes; garden soils, 4–12.5 millions, with 14–62 per cent actinomycetes; woodland soils, 2.5–16.9 millions, with 19–67 per cent actinomycetes; sphagnum raw humus, 0.2–7.0 millions, with 3–29 per cent actinomycetes; and barren soils, 0.1–3.5 millions, with 5–46 per cent actinomycetes.

* Papers from the Department of Botany of the University of Michigan, No. 730.

The samples were not of a composite nature. Had they been, they would have been more significant from the agronomist's point of view, as Waksman and Fred have shown (1922). The variables introduced by the season of the year when the samples were collected,

TABLE I

NUMBERS OF ACTINOMYCETES IN THE SURFACE LAYER OF VARIOUS SOILS

No.	Soil type	Water pct.	pH	Actinomycetes		Month of collection
				Millions per gm.	Pct. of total	
	Garden soils					
1	Loam	18	6.0	12.5	62	October
2	Loam	9	6.0	4.0	25	October
3	Clay	18	6.0	5.4	32	October
4	Clay loam	15	7.0	5.3	14	October
5	Loam	13	6.0	10.5	55	October
6	Loam	24	7.0	5.7	34	October
7	Loam	11	5.5	5.7	50	October
	Grassland soils					
8	Clay loam	15	7.0	25.4	19	June
9	Loam	19	5.0	5.6	25	October
10	Loam	19	7.0	13.1	34	October
11	Loam	12	6.0	10.4	57	October
12	Loam	18	4.5	7.5	36	October
13	Clay loam	20	7.0	18.7	42	March
14	Clay loam	19	7.0	18.6	32	April
15	Clay	18	6.5	10.2	36	April
16	Clay loam	15	6.0	13.7	28	June
17	Loam	14	6.0	11.8	21	October
	Woodland soils					
18	Loam	19	7.0	16.9	40	October
19	Clay	10	7.5	4.8	19	October
20	Loam	22	7.0	8.5	41	October
21	Clay	25	7.0	11.0	52	October
22	Clay	16	6.0	2.5	24	October
23	Loam	28	6.0	9.1	39	October
24	Loam	28	5.5	5.4	67	October
25	Loam	24	5.0	3.2	19	October
26	Clay	23	5.5	5.6	41	October
27	Clay	33	6.0	6.4	19	October

TABLE I (*Concluded*)

No.	Soil type	Water pct.	pH	Actinomycetes		Month of collection
				Millions per gm.	Pct. of total	
	Miscellaneous wet soils					
28	Low meadow, loam....	50	7.0	12.4	31	October
29	Grassland, riverbank, loam.....	48	7.5	6.8	16	October
30	Edge of pond, exposed, clay.....	41	6.5	15.8	30	October
31	Edge of pond, exposed, gravel.....	20	7.0	7.0	70	August
32	Riverbank, exposed....	57	7.5	2.0	6	October
	Bog soils					
33	Sphagnum peat.....	81	5.5	3.9	52	October
34	Sphagnum peat.....	80	5.0	5.0	58	October
35	Sphagnum raw humus.	87	− 3.0	0.6	3	October
36	Sphagnum raw humus.	90	− 3.0	1.0	15	October
37	Sphagnum raw humus.	93	− 3.0	1.5	12	October
38	Sphagnum raw humus.	96	6.0	6.2	10	October
39	Sphagnum raw humus.	95	− 3.0	0.2	4	October
40	Sphagnum raw humus.	98	− 3.0	7.0	29	October
41	Hardwood bog, raw humus	91	6.5	9.8	11	August
	Barren soils					
42	Sand.....	6	6.0	3.5	46	October
43	Clay with limestone...	13	8.0	0.1	5	October
44	Sand.....	10	7.0	1.8	8	August
	Special soils					
45	Pine seedling bed.....	8	6.0	0.3	2	October
46	Railroad embankment, gravel.....	14	7.0	1.6	24	October

by temperature, by mineral content of the soil, to mention but a few, do not warrant a detailed analysis of the data. The following facts stand out, however: (1) Soils with the same vegetation showed great variance in numbers of actinomycetes; (2) The numbers were

high compared with those reported by many other investigators; (3) Organic matter together with a favorable reaction promoted growth. These aspects will be commented on briefly, in turn.

In regard to the great variance in numbers it must be remembered that plate counts are indeed crude estimates of the actual number of actinomycetes in a gram of dry soil. In the soil one individual may overgrow many times the volume of a single gram of soil, and yet in this volume millions of conidia may develop. Conidia, in the author's experience with single-cell isolations, are very likely to grow, whereas short filaments torn from a mycelium are not. Species cultured by the author in sterilized soil differ markedly in their sporulation. Some cover the soil with masses of conidia; in others there is no macroscopic evidence of spores. The plate method for actinomycetes gives primarily the number of conidiospores (and "fragmentation spores") capable of developing on the medium employed. It has been stated repeatedly that environmental factors are responsible for the great variance in actinomycetes in different soils, but the differences in sporulation, perhaps genetical in origin, have been overlooked.

The numbers were high compared with those reported by many investigators; 14 soils out of 46 tested showed a count above 10 millions per gram. There follows a partial but representative record of the findings of other workers. Conn (1913) reported that on his plates about 40 per cent of the soil organisms, or 12–14 millions, were actinomycetes. Krainsky (1914), who first emphasized the use of synthetic media, secured only 20,800, which was, however, about 30 per cent of the total number of organisms that grew. Waksman and Curtis (1918) reported 7,500–2,400,000 in 25 soils from widely different regions. Waksman (1922) found in 51 samples from one plot 8–25 millions per gram. Löhnis (1926) counted 5.5–9.7 millions in field soils used in legume experiments. Subrahmanyan and Norris (1929) studied 50 Indian soils in which the numbers of actinomycetes ranged from 1 to 3 millions, and they were believed to occur only as conidia. Jensen (1930) made counts on 56 Danish soils and found the numbers to be 0–12.7 per gram — only three soils had more than 10 million. Jensen (1934) published counts of 0.1–35.7 millions per gram on 50 Australian soils; eight soils showed over 10 millions. He further made about 50 periodic counts of one soil at weekly or biweekly intervals and secured 3.6–12.4 millions per gram, with four counts

above 10 millions. A part of the variance in results must be due to differences in method, e.g. some investigators used single soil samples and others composite ones; there was no uniformity in media, time of incubation, observation of colonies, or allowance for moisture in the soil.

The importance of organic matter together with a favorable soil reaction is the third item for which Table I gives support. In grasslands, for example, the numbers were uniformly higher than under other plant cover. This vegetation furnished readily decomposable organic matter and a favorable pH. Conn (1916) advanced the idea that actinomycetes flourish in sod and are active in the decomposition of grass roots. The lowness of the numbers in barren soil with a favorable reaction indicates the necessity for organic matter, and the paucity of organisms in raw humus demonstrates the importance of the reaction. The lowness of the numbers in raw humus is better realized when one considers that the water content is about 90 per cent and that the actual numbers in a gram of moist soil are approximately as low as 10,000. In fact, Jensen (1930) found some acid soils with no actinomycetes and proved experimentally the effect of soil reaction on growth of certain organisms. He later (1934) made the interesting observation that there is a correlation with the numbers of bacteria. "Whether this is due to an actual stimulation of the actinomycetes by the bacteria, or to some unknown factor that stimulates both groups of organisms simultaneously, remains an open question, but it is worth noticing that actinomycetes play an important role in the decomposition of dead microbial matter in the soil, so that we might expect an increase in actinomycetes at periods when bacterial numbers run high and much bacterial protoplasm is being produced."

Table II gives the distribution of actinomycetes in different depths of soil from six sites where fresh profiles of Miami clay loam were exposed. None of the soils had recently been disturbed by man, and all supported a vegetation that was essentially grass.

There was a sharp and irregular decline in actinomycetes in progressively lower depths of soil. This finding agrees in general with those of Waksman and Curtis (1916) and of Brown and Benton, as reported by Waksman and Starkey (1931 : 46). The decline in numbers is presumably due to lack of oxygen and organic material. The differences in pH and in water content in various levels were not

TABLE II

Comparative "Counts" of Actinomycetes from Different Depths of Soil, Based on the Number in a Gram of Dry Soil

Site	Date 1942	Surface soil			Two feet		
		pH	Moisture pct.	Actinomycetes	pH	Moisture pct.	Actinomycetes
1	March 22	7	20	18,700,000	7.3	17	3,493,000
2	April 14	7	19	18,600,000	5.5	15	600,000
3	April 15	6.5	18	10,200,000	7	15	970,000
4	May 21	6	15	13,700,000	7	14	1,620,000
5	May 21	7	15	25,400,000	7.5	12	1,900,000
6	June 2	7	14	15,100,000	5.5	13	2,091,000

Site	Date 1942	Four feet			Eight feet		
		pH	Moisture pct.	Actinomycetes	pH	Moisture pct.	Actinomycetes
1	March 22	7.5	11	16,850	..	11	67
2	April 14	5.0	14	402,000	7	7	2
3	April 15	7.5	13	214,000	7.3	12	680
4	May 21	7.5	9	31,200	7.5	11	1,770
5	May 21	7.5	10	27,100	7.5	9	10
6	June 2	7.5	12	52,000	7	11	6,740

TABLE III

The Percentage of Actinomycetes, Compared with the Total Number of Bacteria and Actinomycetes, in Different Depths of Soil

Site	Percentage of actinomycetes			
	Surface	2 feet	4 feet	8 feet
1	42	59	*94*	29
2	32	*55*	51	2.5
3	*36*	30	24	1.4
4	28	31	*48*	25
5	19	*25*	20	3
6	10	19	*25*	1.7

extreme enough to have a marked effect. Failure to develop spores in the lower layers of the soil is also a likely cause of the decrease in plate counts. The author's cultures in sterilized soil (maintained as

stock cultures for studies in variation) show that conidial production is mostly at the surface of the soil. It is also singular that the actinomycetes which developed on the plates from soil at eight feet were invariably asporous on agar media.

The falling off in numbers of actinomycetes at two and four feet is usually proportionately less than that of bacteria, as is seen in Table III. This is in keeping with the findings of others — Waksman and Curtis (1916), for example. In some soils these authors found a higher number of actinomycetes at eight inches than at the surface. They can continue to develop on a lower quantity of nutrient materials than is true of most soil bacteria. At eight feet the bacteria may again be relatively more abundant because of a greater tolerance for low oxygen concentration; the actual numbers are too low, however, for all organisms at this depth to permit close comparisons.

SUMMARY

1. The "number" of actinomycetes found in the surface layer of 46 soils in the vicinity of Ann Arbor, Michigan, ranged from 100,000 to 25,400,000 per gram of dry soil. Fourteen soils showed "counts" of over 10 millions per gram. The percentage in the total bacteria and actinomycete flora was 2–70.

2. The combination of favorable pH and organic matter was usually associated with high counts of actinomycetes.

3. Stock cultures of actinomycetes in sterilized soil have shown extreme differences in the quantity of spores produced. The author believes that plate counts indicate primarily the number of spores in the soil and that specific differences in spore production is a major factor in the great variance in counts.

4. Actinomycetes were studied in six uncultivated soils at the surface and at depths of two, four, and eight feet. The numbers fell off sharply and irregularly as the depth increased. The decline at two and four feet was proportionately less than that for bacteria, but at eight feet the bacteria were again preponderant.

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PRECIPITATION PROSPECTS, 1943–47, FOR OHIO AND NEAR-BY STATES

EDWIN LINCOLN MOSELEY

SOME degree of success in forecasting excessive and deficient rainfall has been obtained by using a cycle of 90.4 years, which is four times the magnetic sun-spot cycle. In New York State early records of rainfall are sufficiently numerous to make possible the forecasting of precipitation in this way. In Michigan and other states of about the same longitude there are few meteorological records which are old enough to be of use, but until quite recently these states contained some very old trees whose stumps still afford a record of rainfall during a period of several times 90.4 years.

When conditions are favorable for tree growth the layer of new wood called the annual ring, formed just beneath the bark, is wider than in unfavorable years. In an area large enough to include counties with various soils and topography, if a majority of the trees whose rings are studied are found to have made a good growth in a certain year, we may be reasonably sure that climatic conditions favored growth at that time.

In the regions where I have studied tree rings I have found a good correlation between ring width and the amount of rain falling in the growing season; this holds true as far back as there are rainfall records for the region. Temperature also affects tree growth, but it varies so little, except for brief periods, that it does not often obscure the effect of rainfall, which is subject to much wider variation at the time when vigorous growth requires a large amount of water.

The effect of plentiful rain or the lack of it may be easily seen by anyone who will examine the end of a log or the top of a sound stump. Knowing that the outermost ring of wood represents the last growing season before the tree was cut down, that the next ring inside it grew the year immediately preceding, and so on, the observer can readily find rings corresponding to any years which he can recall as having been wet or dry.

In Ohio and states near by the summers of 1934 and 1936 were dry;

those of 1935 and 1937 were wet. The rings which record the growth of the tree in these summers will show the effect of these differences in rainfall. The summer of 1925 was dry; in 1927 and 1928 there was abundant rain. This also is plainly revealed by the corresponding tree rings.

The earliest of the very dry summers in my recollection was that of 1871, when forest fires in Michigan and Wisconsin drove many families from their homes and when there occurred at Chicago one of the most destructive fires in human history. Weather records and tree rings show that both 1870 and 1871 were dry.

If one counts the rings from that of 1870 back toward the center of a stump until he has reached ninety, he finds that the ring formed in that year, 1780, is outstanding as a narrow one. That was a dry year in Washtenaw, Lenawee, Cass, and Berrien counties, Michigan, in all of which I have cut sections from stumps of old trees. It was dry also in the Allegheny State Forest in western Pennsylvania and in the neighborhood of Easton in eastern Pennsylvania, in different parts of Ohio, and in Indiana, Kentucky, and northeast Louisiana. We know that earlier still, at intervals of 90 or 91 years, rain was not sufficient to enable the trees to make a good growth.

The years 1872 and 1874 were also dry; 1873 and 1875 had more than average rain in parts of some states near Ohio, but none of the six years 1870–75 yielded as much rain as the average of the nine following years. Measurements of the radial growth made by a large number of trees during these six years and the next nine years, 1876–84, show that in a majority of them it was more than one and one-half times as great in the longer period. The same results hold for six- and nine-year periods antedating these by 90 years, and also in corresponding periods 91 years earlier still. Tree growth in other short periods of years has been measured with similar results — after 90 or 91 years wet periods are followed by wet periods, dry periods by dry periods.

The early periods in which we are now most interested are those that correspond to the present and the immediate future. I have measured the growth in 1846–52 of more than 250 trees and the growth of nearly as many in the preceding six or seven years. My measurements of the years following 1852 began somewhat later than those preceding, and for a time I was uncertain how many rings I should measure, but soon found that the five years after 1852 gave a strong contrast in growth rate with the seven years ending

with 1852, so that I have used 1853–57 in most of the measurements which I have made since the summer of 1937. For the period preceding 1846 all recent measurements have included the seven years 1839–45. In almost every area where the trees were studied, from southern Michigan and northern Pennsylvania to southern Tennessee, a majority made more growth in 1846–52 than in the preceding seven years. In the five-year period after 1852 a majority grew more slowly.

Ninety years earlier we again find a strong contrast in growth rate between periods corresponding to those just mentioned. In 1756–62 trees grew decidedly faster than in the preceding seven years or in the ensuing five years. Likewise, in the previous century they grew faster in 1665–71 than in the seven years preceding or in the five years following. This is true also of the corresponding periods in the sixteenth century.

Extending this series of dry and wet periods to the twentieth century, we find that our recollection as well as weather records and tree rings show there was a shortage of rain in the period of nearly seven years beginning with 1930. Since late summer in 1936 rainfall has averaged greater in most places, as was predicted. The twelve-month period ending with May, 1942, was an exception; this also was predicted. After that there was plenty of rain until October. From then until the present, March, 1943, the average rainfall for the whole period has been near normal. It remains to be seen whether this seven-year period which, taken as a whole, was expected to afford more than average rain, will end with a grand finale in the coming spring as I expect it to.

It is probable that in the summer and fall of 1943 we shall have much less rain than we had in these seasons in 1942; at many places there is likely to be somewhat less than usual, but I have no reason to expect a drought anywhere east of the Mississippi, then or later, until about the middle of 1946. I expect the rainfall to be much above average in the latter part of 1945 and the early part of 1946.

A severe drought affecting many states should be anticipated for the latter half of 1946 and the greater part of 1947. After that for many years this part of our country will probably not experience so serious a drought.

The probability of this drought comes from the fact that there has been a drought at every corresponding period as far back as we have

any tree record; the earliest that we know about was two years after Columbus's first voyage to America. Only four of our trees, two hemlocks in Pennsylvania and two white oaks in Ohio, were growing in 1494, but each of these formed a very narrow ring that year. Ninety years later there was another severe drought. We have sections from twenty-two trees that were growing then in this part of the United States. The next droughts in this series occurred in 1675, 1765, and 1856.

The severity of the drought of 1856 is attested by weather reports as well as by tree rings. Records of precipitation for that year have been preserved for thirteen places in Ohio, of which four are in the northern part of the state; at three in central and western Pennsylvania; at two in Kentucky; and at Richmond, Indiana. At every one of these nineteen places rainfall in 1856 was below normal; in most of them it was much below. The great state of Michigan has one place whose record includes 1856 — Fort Brady, Chippewa County; it is incomplete, but in the first eight months of that year the total rainfall was only 7.26 inches.

In Illinois six places have records for 1856; at five of them rain was below normal, but at only two was it very far below. In that year St. Louis had three inches of rain more than average, and Oregon in the same state a fraction of an inch more than average. In eastern Iowa there was some shortage at three places, but a larger surplus at three others.

Leavenworth, Kansas, had plenty of rain in 1856, but not in either 1854 or 1855. At St. Paul, Minnesota, less than six inches of rain fell in the whole growing season of 1856, but the year's total was 27.04 inches. Milwaukee got a little less than usual that year; it was much less than in either of the two years preceding.

One fact which has been impressed upon me recently will be of particular interest to people living in and near southern Michigan — the region near the Great Lakes is less affected by droughts or floods than are states farther south, as well as less than those farther west. The drought of 1930–36 was more serious in the latitude of Kentucky than in that of Michigan, and farther west it was more serious in other latitudes also. In the summer of 1936 I went to the Pacific Coast by way of North Dakota and Montana, returning by way of southern California and Kansas. Almost everywhere along the way, except where the land was irrigated, crops were suffering for lack of

rain, and in many places they had failed in several preceding years. In northern Indiana they were better, and in northern Ohio they were rather good. In Wood County and doubtless in some others in northern Ohio there has been no general crop failure for a great many years. Throughout most of the West such counties are scarce or entirely wanting unless the land is irrigated.

In the Kentucky area, too, devastating floods are more frequent than they are farther north. In January, 1937, nearly as much rain fell on a large part of Tennessee and Kentucky as at Ann Arbor in the entire year of 1934.

This difference between the two latitudes was true in the nineteenth century likewise and before that. In Jefferson County, Kentucky, in which Louisville is located, the average annual rainfall in 1846–52 was twelve inches more than in the five following years, and at Cincinnati it was 12.44 inches more. My tree-ring measurements show greater differences in growth, owing to greater differences in water supply, in that region than farther north. This is true also of the corresponding periods ninety years earlier still (see Table I).

Table II shows that at all stations where records were made rainfall was above average in 1850 and 1855 and at all except Portsmouth in 1852. In 1856 it was below average at all stations. In such cases there is much probability that similar weather will occur over a great part of the same area about 90.4 years later. In the years 1853 and 1854 there was no such agreement among the stations. This causes difficulty in making forecasts for the two years beginning in the summer of 1943. The tree rings in the eighteenth century show a greater preponderance of dry weather during the corresponding period than in the nineteenth. On the whole, it seems probable that in the two years following the spring of this year (1943) somewhat less than the usual amount of rain will fall on the area I have been studying, but that in much of it rain will be about as usual and in some of it more than usual. Compared with recent years, there should be less danger from floods, less trouble in harvesting crops and in working land that is too wet.

Further data either from tree rings or from unpublished records of rainfall in the middle of the last century may make possible more precise statements regarding probable future rainfall in different areas.

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TABLE I

Tree Growth in the Parts of the Five Previous Centuries Which Correspond to the Present Part of the Twentieth

Area	Counties	1839-45	1846-52	1846-52	1853-57	1749-55	1756-62	1756-62	1763-67	1658-64	1665-71	1665-71	1672-76	1568-74	1575-81	1575-81	1582-86	1477-83	1484-90	1484-90	1491-95
Southern Michigan and adjacent parts of Indiana and Ohio	7	6	33	22	20	11	21	21	12	6	9	7	12	1	6	3	2	0	1	1	0
Northern Ohio, vicinity of Bowling Green	4	4	22	15	5	9	13	20	0	2	7	3	1	0	1	..	..	..	..	..	..
Central Ohio, vicinity of Marion	2	4	14	15	4	8	10	15	6	4	8	7	3	2	2	2	1	1	0	..	..
Southwestern Ohio	5	2	13	11	3	6	9	7	4	1	4	1	4	..	..	..	..	..	..	..	..
Southern Kentucky near Burnside... Northern Tennessee near Oneida	6	20	28	22	0	7	22	12	1	0	1	0	1	0	1	1	0	..	..	..	..
Western half of Tennessee, logs at mills.	12	9	14	6	2	4	10	3	1	..	..	..	..	..	..	..	..	..	..	..	..
Northeastern Louisiana, West Carroll Parish	2	7	11	12	3	3	6	2	4	..	..	..	..	..	..	..	..	..	..	..	..
Southern Indiana and adjacent Kentucky	7	2	6	1	0	0	14	1	0	..	..	..	..	..	..	..	..	..	..	..	..
Northwestern Pennsylvania, Allegheny State Forest	1	2	4	5	1	1	6	4	1	4	0	3	2	0	3	1	0	2	0	2	0
Northeastern Pennsylvania near Easton	3	4	3	4	2	0	2	2	0	..	..	..	..	..	..	..	..	..	..	..	..

Numbers record how many trees grew faster in the period indicated at the top of the column than in the period at the top of the adjacent column. Measurements showing approximately equal rates are not included.

TABLE II

PRECIPITATION IN THE PART OF THE NINETEENTH CENTURY WHICH CORRESPONDS TO THE PRESENT PART OF THE TWENTIETH *

Area	Normal	1839–45	Departure	1846–52	Departure	1853–57	Departure	1850	1851	1852	1853	1854	1855	1856	1857
OHIO															
Cincinnati	40.38	43.00	+ 2.62	51.82	+ 11.44	39.38	− 1.00	54.76	31.70	54.06	41.23	50.77	47.19	22.85	34.88
Marietta	42.25	38.52	− 3.73	45.49	+ 3.24	38.94	− 3.31	52.36	39.94	46.50	37.04	38.80	45.75	32.46	40.64
Steubenville	41.15	36.6–	− 4.55	47.42	+ 6.27	40.22	− 0.93	46.98	28.59	49.30	35.50	30.11	47.93	32.35	54.98
Portsmouth	41.06	40.57	− 0.49	43.7	+ 2.64	..	..	57.20	30.97	39.62	28.74	31.33	48.51	..	..
Dayton, 1846–49	39.76	..	..	56.21	+ 16.45	..	..	..	..	..	..	..	..	..	..
Germantown,† 1853–56	38.51	..	..	..	..	36.1	− 2.41	..	36.28	41.18	28.54	44 72	47.00	24.15	..
Urbana	39.84	..	..	..	..	42.54	+ 2.70	..	..	58.84	45.20	41.35	57.47	30.85	39.82
North Lewisburg	40.19	..	..	..	..	..	..	..	..	58.35	45.10	41.25	57.50	31.90	38.85
Hudson	37.92	33.84	− 4.08	..	..	..	..	..	..	..	..	..	..	..	..
OTHER STATES															
Richmond, Ind.	40.42	..	..	..	..	39.38	− 1.04	..	..	46.36	31.97	45.06	56.77	23.32	39.30
Springdale, Ky.‡	48.40	43.17	− 5.23	51.84	+ 3.44	39.84	− 8.56	67.10	42.34	51.91	35.56	46.20	..	30.91	46.70
Pittsburgh, Pa.	36.07	33.2	− 2.87	38.77	+ 2.7	33.83	− 2.24	37.41	29.64	41.36	33.63	26.67	43.33	26.59	38.96
Lebanon, Pa.	43.63	36.41	− 7.22	44.02	+ 0.39	43.26	− 0.37	64.12	35.50	43.90	43.11	37.58	53.63	31.55	50.61
Gettysburg, Pa.	40.79	37.61	− 3.18	41.17	+ 0.38	36.08	− 4.71	45.63	30.99	43.31	32.08	33.86	47.62	28.63	38.23

* Data were missing where leaders occur.

† Dayton and Germantown are in Montgomery County; Urbana and North Lewisburg, in Champaign County.

‡ Data for 1839, 1840, and 1855 are lacking.

ECOLOGICAL STUDIES OF PIERPORT, BEAR LAKE, AND EDGEWATER BOGS IN MICHIGAN

IRVING E. W. OLSON

DURING the summer of 1935 I became interested in the large number of bogs in the west-central portion of the Southern Peninsula of Michigan. I observed that they differed somewhat in floristics and structure from the generally accepted concept of bog succession as set forth by the earlier investigators of bogs in the Huron River valley, and, more recently, by others in the region of Douglas Lake, where the University of Michigan Biological Station is located. Furthermore, I noted that there was a scarcity of literature, especially on floristics and succession in bogs.

Up to the present time ecological studies of bogs in Michigan have been limited almost entirely to two widely separated regions: the Huron River valley, in the southeastern part of the Southern Peninsula, where the earlier investigations were conducted, and the Douglas Lake region far to the north, where more recent studies have been carried out by students and staff of the Biological Station. The only other places where bogs have been studied are: North Manitou Island (Transeau, 1903); on Isle Royale, in Lake Superior (Cooper, 1912); in the extreme southwestern part of the state, at Baroda, in Berrien County (Kurz, 1928) and at Hartford, in Van Buren County (Osvald, 1935); and numerous bogs occurring throughout the Southern Peninsula as listed by Davis (1907), who has done much work on peat deposits in Michigan. According to Davis, bogs are frequent throughout the state; however, a number listed by him in 1907 have since changed considerably because of drainage of lands for agricultural purposes. For example, Four Mile Lake, west of Dexter, in Washtenaw County, which used to have a bog, shows the effect of drainage in that the characteristic bog plants have disappeared, and this once large lake is now little more than a grassy lowland and mud flat with a small stream draining it.

During the summers of 1935, 1936, 1939, and 1941 I visited twenty bogs in the west third of the central region of the Southern Peninsula of Michigan. This area is bounded roughly by a line extending from Grand Rapids, in Kent County, northward about 250 miles to Kalkaska, in Kalkaska County, and westward to Lake Michigan. Since it was not practicable to visit every bog within this area, those chosen will serve, for the purposes of this paper, as examples of the types that occur in it. That many more than those listed might be found in this section is quite possible, for in driving through it one often sees in the distance the characteristic trees — tamarack and spruce — that grow on bogs.

From the studies made to date of the bogs in this area I suggest that many of them have followed different courses in their development from those given in the generally accepted concept of plant succession on bogs. Since field investigations of succession thus far made are not conclusive, further studies are planned.

Plant succession on bogs as outlined by Weaver and Clements (1929) is reviewed briefly as follows:

1. Submerged stage: plants in open water up to 20-foot depths, prominent among which are Potamogeton, Myriophyllum, and Elodea.
2. Floating stage: plants in water 6 to 8 feet deep, largely Nymphaea and Polygonum.
3. Floating mat stage: composed essentially of Carex species; occasionally Decodon is the mat former.
4. Moss — low-shrub stage: Sphagnum, Menyanthes, Drosera, Sarracenia, and others, followed by shrubs such as Andromeda, Ledum, and Chamaedaphne.
5. Bog-tree stage: principal trees, Larix and *Picea mariana*.
6. Climax forest: *Pinus Strobus* in the Great Lakes forest.

This report will be restricted to three bogs in a region in which no bogs have been described, with notes on their floristics and physiognomy. Two lie near Bear Lake, in Manistee County; one is in the Platte Plains, in Benzie County.

Bogs Visited

The bogs studied are grouped according to stability of substratum and physiognomy of vegetation:

Group A. Bogs with stable substratum and open water; mainly low plants;

Group B. Bogs with stable substratum and no open water;

Group C. Bogs with stable substratum and more or less tree cover.

GROUP A. BOGS WITH STABLE SUBSTRATUM AND OPEN WATER; MAINLY LOW PLANTS

Water is present; mat is quaking or partly quaking; Chamaedaphne scrub with few to many tamaracks; spruce may or may not occur; when it does, it becomes well established; pine, when found, is usually on the firmer areas of the mat.

1. Pierport Bog. Along Highway M–22, in Manistee County, midway between Frankfort and Manistee, and one mile east of the village of Pierport.
2. Bog at Big Bay of Bear Lake. In Manistee County, northwest of the village of Bear Lake, along Highway U.S.–31.
3. Mud Lake Bog. In Newaygo County, along Highway M–37 just south of Bitely. The lake was formerly known as Placid Lake.
4. Greenan Bog. Just south of Mud Lake Bog. Named for the owner of the property on which it is located.
5. Newaygo Bog. In Newaygo County, about two miles north of Newaygo, to the west of Highway M–37.
6. Aman Lake Bog. At Aman Park, in Ottawa County, eight miles west of Grand Rapids, along Highway M–50.
7. Bog about four miles east of Grand Rapids, in Kent County, along Highway M–50.
8. Bog about three miles north of Grand Rapids, in Kent County, along a county road.
9. Dead River Bog. In Benzie County, lying between the two Platte lakes.
10. Sugar Loaf Bog. In Kalamazoo County, just south of Portage, along Highway U.S.–131.
11. Spring Run Bog. In St. Joseph County, at Spring Run, about three miles north of Moore Park, along Highway U.S.–131.
12. Prairie River Bog. In St. Joseph County, about two miles south of Three Rivers, at Prairie River, along Highway U.S.–131.

GROUP B. BOGS WITH STABLE SUBSTRATUM AND NO OPEN WATER

Chamaedaphne meadow with tamarack or spruce or both; open water not present; mat not quaking.

13. Bog west of Blue Lake. In Newaygo County, about one and one-half miles south of Brohman and east of Highway M–37.
14. Mud Pond Bog. In Benzie County, near the mouth of Platte River, along Highway M–22.
15. Walkerville Bog. In Oceana County, about two miles north of the village of Walkerville, along either side of county road.
16. Gordon Lake Bog. In Manistee County, about four and one-half miles south and west of the village of Bear Lake.

17. Bog near Grass Lake. In St. Joseph County, three miles west of White Pigeon, along Highway U.S.–112.
18. Bog along county road. In Kalkaska County, about five miles west of the village of Kalkaska.

GROUP C. BOGS WITH STABLE SUBSTRATUM AMD MORE OR LESS TREE COVER

Chamaedaphne meadow being shaded out by spruce and pine; mat is becoming quite firm as the forest advances on it.

19. Edgewater Bog. In Benzie County, about thirteen miles north of Frankfort and one-eighth mile east of Benzie County State Park, along Highway M–22.
20. Little Bay Bog of Bear Lake. In Manistee County, north and west of the village of Bear Lake, along Highway M–51, at Little Bay.

GEOLOGY OF THE REGION

The Southern Peninsula of Michigan lies in the eastern lake section of the central lowland province east of the Mississippi River (Fenneman, 1938). In this part of the state at least five distinct glacial periods can be traced back by moraines that are the result of numerous advances and recessions of continental glaciers. Although it is not the purpose of this study to include a detailed discussion of the history and development of these glaciers, a brief account of some of the outstanding physiographic features of the area about each bog will be given.

The general region in which the bogs studied in detail are located is roughly that lying between the terminal moraine of the Lake Michigan glacial lobe (Chamberlin, 1883) and the present shoreline of Lake Michigan in Manistee and Benzie counties.

The texture and composition of the soils in this area vary greatly and include rich humous soils formed from peat beds, loamy and gravelly soils of outwash plains, and rather extensive areas of sandy soils, both ice- and wind-borne. These sandy soils are acid in reaction and were often covered with nearly pure stands of pine, commonly referred to as "pineries" in the prelumbering days.

The Southern Peninsula is dotted with lakes, large and small, which resulted chiefly from glacial action. Some are pits in outwash plains where stagnant ice blocks melted; others have been formed by wind-blown sand deposited across outlets of large shallow basins or in depressions between ridges. In many of these lakes

in places where drainage was retarded or completely shut off conditions were favorable for the development of bogs, which are quite common throughout the Southern Peninsula.

Description of Three Bogs in West-Central Michigan

The three bogs in west-central Michigan that were studied in detail lie in the lowlands between ridges in the Manistee moraine, which extends northward from Manistee along the shores of Lake Michigan through Benzie County and into Leelanau County. This moraine curves around the ends of transverse sand ridges that come out as headlands along this part of the shore of Lake Michigan. Between these ridges the ice pushed into the lowlands for several miles from the shore of the lake, so that the moraine makes a series of loops in crossing the lowlands between the prominent ridges.

Bear Lake was formed as a pit on an outwash plain between two spurs of this moraine. One of the largest bogs in the region has its origin on Big Bay of the lake.

The first bog to be described lies in a small depression on the moraine itself. The second occurs on Bear Lake. The third lies between two sand ridges in the extensive sand plains known as Platte Plains.

1. Pierport Bog

Location

Owing to its proximity to the village of Pierport, just one mile to the west on the shores of Lake Michigan, the bog surrounding a small lake known locally as Kuenzer's Lake will be designated "Pierport Bog" (Fig. 1). It is in the extreme northwestern section of Onekama Township, Manistee County, Section 3, R. 24 N., T. 16 W. It is readily accessible and begins approximately 300 feet to the west of Highway M–22, about midway between Frankfort and Manistee.

The bog has formed completely around a somewhat circular lake in a depression in the morainal deposits along Lake Michigan. It covers slightly over seven acres, of which about three are open water. The level of the lake at the present time is approximately fifty feet below the general level of the upland, which rises rather abruptly in all directions from the edge of the bog except to the

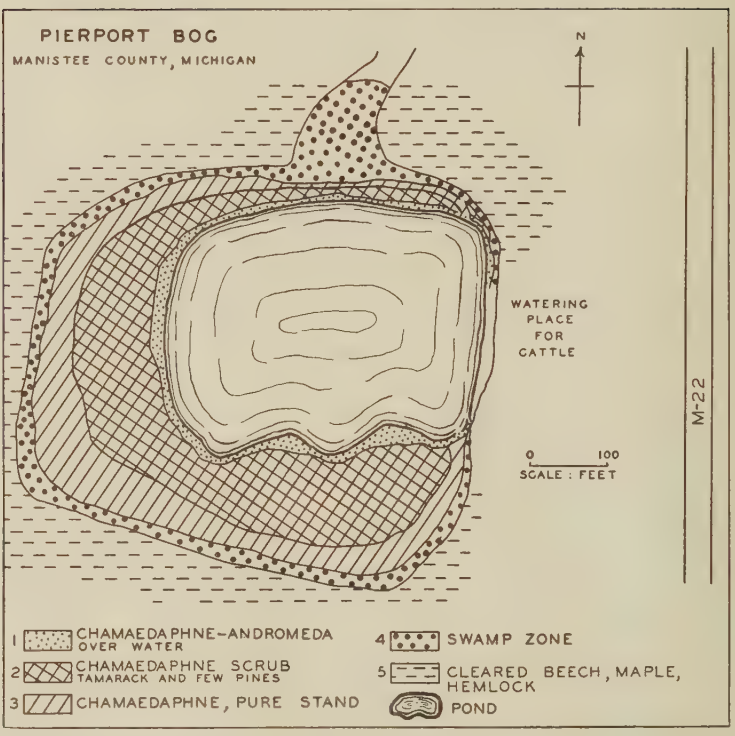

Fig. 1

(In the text the various areas of Figures 1–3 are called "zones.")

north, where a narrow ravine extends gradually to the upland for a distance of about 500 feet.

The lake and surrounding bog are a part of a 160-acre farm owned in 1936 by Mrs. R. W. Todd, of Bangor, Michigan. Nearly all the farm has been under cultivation for many years, most of which is at present in pasture land. There is no apparent drainage, and the lake is probably still fed by hidden springs. A large one at the head of the ravine to the north formerly fed the lake, but ceased flowing some thirty-five years ago. The entire bog is accessible to cattle, which graze on the surrounding upland. The swamp zone at the east end of the lake is devoid of vegetation.

Early History

For data on the early history of this bog and the surrounding area I am indebted to Mr. O. C. Kuenzer, R. F. D. 1, Bear Lake, Michigan. In an interview in August, 1936, he gave me a vivid description of conditions as they existed in 1875, the year in which the general tract containing his father's farm, on which the bog is located, was homesteaded. He was nine years old when he came to this farm, on which he worked until the forest fires of 1885 forced the family to move to a near-by farm. He was in a position to describe many changes in the vegetation resulting from the clearing of the forests as well as to give information on which the historical account of this paper is based.

When this tract was homesteaded, the farm and the land around it were completely forested with beech, maple, and hemlock — the beech and maple predominating to the south, west, and north. To the east, across the present Highway M–22, there was a nearly pure stand of hemlock covering several square miles of land. On the upland to the north were two spruces, the only ones known in the vicinity. These were cut for Christmas trees in 1895. A small number of pines were scattered throughout the region, and a few balsam firs were seen as recently as 1900.

In 1885 a local fire that devastated several square miles of forest land began to the southeast of the bog and spread to a three-mile front. It burned all the vegetation to the ground and reached the shores of the lake on the west and the south. On the upland to the east of the lake two white pines with diameters of 22 and 30 inches were not damaged by the flames and are still standing. A pine and two hemlocks on the south shore survived the fire, as did a pine and a hemlock on the north shore. All of these trees were large. The pines were cut for lumber about 1900; the hemlocks, in 1910.

The water level of the lake, which, as has been stated, was fed by a large spring coming from the upland to the north, has been lowered about six feet. The flow of water from it gradually decreased after the fire and the clearing of the subsequent second growth of trees until it ceased in 1910. Before the lake dropped to the present level a moat with an average depth of six feet of water and a width of from ten to twelve feet had to be crossed to

get on the mat. The mat was accessible by foot in only one or two places; a boat was generally used to reach the mat for the gathering of cranberries. A number of the large logs, all of which were under water until 1905, can still be seen at the south edge of the present mat.

Witch-hazel and lady-slipper orchids used to be found here in abundance, the former in the swamp zone along the wooded upland and the latter on the bog mat. In this area there have been no oaks since the fire of 1885. Three species of cranberry, one red, one red and white, and one grayish, were plentiful on the mat. The grayish berry may have been the creeping snowberry now sparsely distributed over the mat. Before the lowering of the level of the lake, limeweed, a local name for pondweed, covered the water along much more of the shoreline than it does now.

During the years 1917–18 a considerable amount of peat was removed from the south border of the present mat and hauled to the uplands to the south as a fertilizer. In this disturbed area some grasses have come in from the surrounding upland, which has been in pasture for many years.

About 1930, when the larch sawfly killed many tamaracks in the general area, the tamaracks on the mat began to show a decided lack of vitality and growth, and many of the larger trees have since died, probably because of the ravages of the fly.

Floristics and Zonation

In the lake are three distinct areas of *Nymphaea advena* Ait.,[1] the largest of which is along the east shore. The other two lie along the east and west shores.

In Zone 1 (Fig. 1) rooted in a dense mat of Sphagnum is a heavy stand of *Chamaedaphne calyculata* (L.) and *Andromeda glaucophylla* Link. The branches of many plants of both species extend out over the water from two to four feet, and where the tips of these branches touch the water, roots develop at the nodes. This suggests the possibility of these shrubs appearing as pioneer plants or mat formers in the development of bogs in this general area. This zone is well defined and reaches completely around the lake, except

[1] With the exception of the genus name Polytrichum, the names used in the identification of plants listed in this study are those of *Gray's New Manual of Botany*.

for a small area along the east shore, where vegetation has been trampled out by cattle coming for water. On the south are two protrusions where the Chamaedaphne–Andromeda mat appears to be spreading over the water at a rate faster than that on the rest of the mat. To the east and northeast such protrusions are smaller and less obvious, although readily recognized. According to local testimony, the mat has advanced noticeably and rather uniformly over the water about ten feet since 1905.

In Zone 2 Chamaedaphne is the dominant shrub, with Andromeda less frequent. This portion of the mat is also quaking and contains a heavy stand of Sphagnum, with which the following plants are commonly associated: *Vaccinium Oxycoccus* L., *Drosera rotundifolia* L., *Kalmia polifolia* Wang., *Sarracenia purpurea* L., *Eriophorum angustifolium* Roth., and *Eriophorum viridi-carinatum* (Engelm.) Fernald. Less common plants are *Menyanthes trifoliata* L., *Chiogenes hispidula* (L.) T. & G., *Eriocaulon articulatum* (Huds.) Morong., and *Hypericum spp.* Only two plants of *Habenaria blephariglottis* (Willd.) Torr. have been observed on the mat, both of which blossomed in July, 1935. *Larix laricina* (DuRoi) Koch. is very abundant in this zone and also in Zones 1 and 3. In Zone 1 a number of the trees grow along the water's edge; in Zone 2 an exceptionally heavy stand of tamarack is becoming established south of the pond at the east and at the west and northwest portions of the mat. As previously stated by Mr. Kuenzer, many of the larger trees have died since 1930. Examination based on a count of growth rings in several large dead trees indicated growing periods ranging from 90 to 120 years. Some of these trees may have been killed by the sawfly, which is known to have destroyed many tamaracks in this part of the state.

In Zone 3 the mat is partly quaking, with a practically pure stand of Chamaedaphne. In some sections Chamaedaphne appears to be thinning out, especially in the southwest, where the large trees on the edges of the upland partly shade the mat. Tamarack is common in the zone, but white birch (*Betula papyrifera* Marsh.) is invading the mat and reaching into Zone 3 and even to the edge of the water in Zone 1. Ten or twelve trees of *Pinus Strobus* L., together with a few seedlings, are on the mat. These have probably developed from cones from the two pines on the upland to the east that survived the fire of 1885. Two or three small hemlocks (*Tsuga*

canadensis (L.) Carr.) and several beeches (*Fagus grandifolia* Ehrh.) have also invaded the quaking portions of the mat to the south of the pond.

In Zone 4 the swamp zone is relatively dry. Since about 1900, when the large spring feeding the lake from the uplands began to fail, the level of the lake has dropped about six feet, as has already been noted. In 1905 the logs of hemlock, which are still found in the moat, began to show above the water, which at one time was six feet deep. In this zone the following plants occur: *Cephalanthus occidentalis* L., *Sambucus canadensis* L., *Lonicera caerulea* L. var. *villosa* (Michx.) T. & G., *Salix sericea* Marsh., *Ilex verticillata* (L.) Gray, *Rubus idaeus* L. var. *aculeatissimus* (C. A. Mey.) Regel & Tiling, *Potentilla palustris* (L.) Scop., and *Alnus incana* (L.) Moench. In the portions of this zone to the south, where peat was dug in 1918, and to the east and north of the watering place for cattle *Scirpus cyperinus* (L.) Kunth var. *pelius* Fernald, *Carex trisperma* Dewey, and *Juncus effusus* L. are found. Other plants growing locally in the swamp zone are: *Polytrichum spp.*, *Maianthemum canadense* Desf., seedlings of wild cherry (*Prunus virginiana* L.), *Ribes vulgare* Lam., *Fragaria virginiana* Duchesne, *Rosa carolina* L., *Solanum Dulcamara* L., and *Woodwardia virginica* (L.) Sm.

On the upland slope to the east there are a number of large hemlocks, red maples (*Acer rubrum* L.), hard maples (*Acer saccharum* Marsh.), white birches (*Betula papyrifera*), and sweet birches (*Betula lenta* L.). Under these trees are also bracken (*Pteris aquilina* L.) and wintergreen (*Gaultheria procumbens* L.). A species of blueberry (*Vaccinium sp.*) is invading the mat over the more stable portions. Along the southwest edge of the mat is a clump of wild cherry (*Prunus virginiana*), with white birch (*Betula papyrifera*). On the edge of the mat winterberry (*Ilex verticillata*) and serviceberry (*Amelanchier canadensis* (L.) Medic.) are thriving locally to the north and northwest.

On the upland to the north and extending eastward around the swamp zone and south to the watering place for cattle one finds the following plants: white birch (*Betula papyrifera*), sweet birch (*Betula lenta*), hard maple (*Acer saccharum*), large-toothed poplar (*Populus grandidentata* Michx.), hemlock (*Tsuga canadensis*), white pine (*Pinus Strobus*), and serviceberry (*Amelanchier canadensis*). Ground plants among these trees include bracken (*Pteris aquilina*),

blueberry (*Vaccinium spp.*), *Polytrichum spp.*, and cinnamon fern (*Osmunda cinnamomea* L.).

In July, 1941, it was noted that the level of the lake had dropped about one foot since 1925, exposing the mud of the Nymphaea zones above the surface of the water, but the reason for the lowering is not known.

Borings were made in a number of places on the mat to the south of the lake. The greatest depth, 27 feet 4 inches, was reached in Zone 2, about 100 feet south of the edge of the mat, where the peat was found to be deposited on sand.

According to Mr. Kuenzer, the mat was very narrow in front of a pine tree which stands near the edge of the mat along the northwest shore of the lake, for there was just room for him to stand on the mat between the tree and the water when he fished in the lake for the last time in 1905. In July, 1941, it extended out over the water from the base of the pine tree exactly fifteen feet. The mat has apparently grown out over the water at this point at the rate of about one foot every three years. The diameter of the pine tree was nine and one-half inches four feet above the mat.

2. BEAR LAKE BOG

Location

Bear Lake Bog (Fig. 2) lies in Sections 25 and 36 of Arcadia Township and Sections 30 and 31 of Pleasanton Township, Manistee County, Ranges 15–16 and 23–24 N.

The floating mat is most easily reached by following the improved road south and west around the south shore of Bear Lake to the lakeside cottage camp and by hiking from this point northward to the area of Big Bay along the shore of the lake. The more mature portion of the bog, indicated on the map as Zone 3, is readily reached from any place along the beach of Bear Lake in the area of Big Bay.

The bog itself has formed over Big Bay along the shores of Bear Lake to the uplands and extends northwestwardly for nearly a mile.

Geological Features

Bear Lake is in the northwestern part of Manistee County about midway between Manistee and Beulah. At the east end of the lake is the village of Bear Lake.

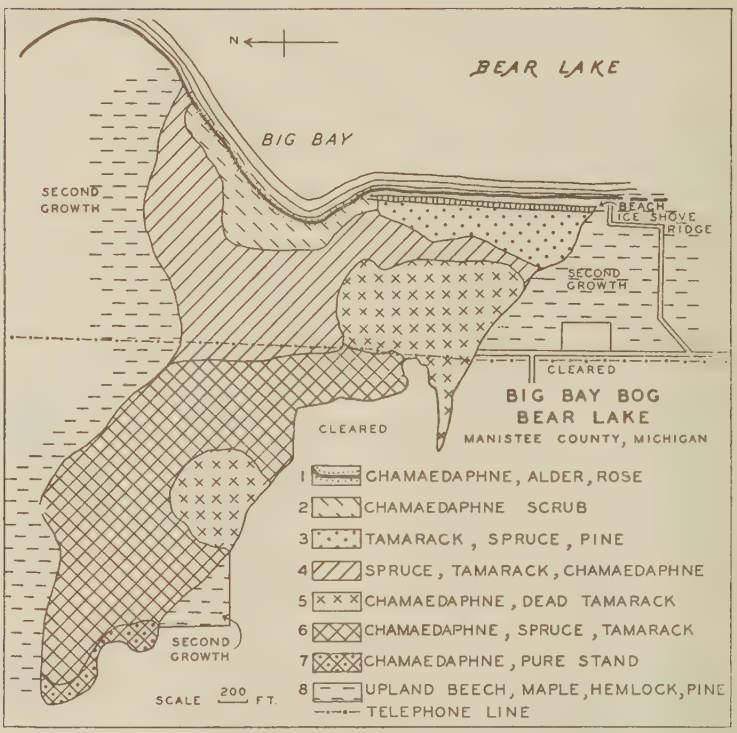

Fig. 2

This lake, an open expanse of water of very regular outline and with dimensions of about two and one-fourth and one and one-fourth miles (Scott, 1921), covers an area of 1,744 acres. The longer axis lies in an east-west direction. The western part of the basin hardly exceeds fifteen feet in depth, but depths of fifty to sixty feet are known for the eastern part. The original outlet, which flowed from the east end, was shifted somewhat to the south when the road was built. The present lack of a definite channel and, possibly, the obstructing road may account for occasional higher water levels of the lake. However, the cause of high water has not been definitely determined.

The glacial formations may readily be made out as one approaches

the lake on the road from the south. At first the route is through a rugged moraine, from the crest of which a broad outwash plain below reaches northward to another moraine some six miles away. Beyond the crest the moraine slopes sharply to the north, and the entire lake appears to view; it extends from the foot of the slope to the outwash. The basin is bounded on the east by upland, but stretches eastward as a low heavily wooded swamp to Bear Creek several miles distant. In brief, the lake basin is part of a depression in the outwash at its junction with the moraine. The soil map for the county shows that the soil for about a mile north of the lake and west about two and one-half miles is classed as Rubicon loamy sand. The entire area of the several bogs around the lake, together with that of Pierport Bog, is included in the region of this sand.

Early History

Information regarding the vegetation of the area before the days of lumbering was obtained from Mr. O. C. Kuenzer. According to him, the area for many square miles between Lake Michigan and Bear Lake was heavily forested with beech, maple, and hemlock, and a pure stand of hemlock grew just east of the Pierport Bog, about two miles distant from the shores of Bear Lake. Along the south and west shores of Bear Lake was a rather extensive area with a nearly pure stand of white pine. Local fires did not occur in this immediate vicinity; the nearest one stopped at the edge of the lake on which Pierport Bog is located. The heavy timber was removed during the lumbering operations from 1880 to 1900. With the exception of a small patch of mixed second-growth timber along the north half of the west shore of Bear Lake, now used as a resort, all the upland along this shore is now under cultivation. To the north the cultivated areas extend to the edge of the bog at Big Bay.

Floristics and Zonation

The sandy ridge indicated on the map (Fig. 2) as "ice-shove ridge" is about five feet high and from five to ten feet wide. According to report, this sandy ridge was built up during the lumbering days by the action of lake ice. On it the following plants occur: *Acer rubrum, Acer saccharum, Alnus incana, Amelanchier canadensis, Pyrus arbutifolia* (L.) L. f., *Betula alba* (L.), *Betula papyrifera,*

Gaylussacia spp., *Ilex verticillata*, *Nemopanthus mucronata* (L.) Trel., *Pinus Strobus*, blueberries (*Vaccinium spp.*), *Viburnum cassanoides* L., *Viburnum acerifolium* L., *Viburnum Opulus* L. var. *americanum* (Mill.) Ait., and *Woodwardia virginica*.

Along the beach to the east of the sand ridge the following plants appear: *Scirpus americanus* Pers., *Scirpus validus* Vahl., *Eupatorium perfoliatum* L., *Scutellaria galericulata* L., *Mentha piperita* L., *Utricularia resupinata* B. D. Greene, *Hypericum spp.*, *Gerardia spp.*, *Aster spp.*, and *Solidago spp.*

The bog at Big Bay is the largest of the many which I visited. It extends in a southwesterly direction from the shore of the lake more than 4,000 feet. Its width is about 1,400 feet in the region of the telephone line, which crosses the mat at a line approximately 1,000 feet west of the shore of the lake. All along the edge of the floating mat it reaches around Big Bay northward some 2,400 feet from the north end of the "ice-shove ridge."

Zonation on this bog is probably not so readily observed as the map would indicate. Along the edge of the floating mat is a narrow fringe (Zone 1) in which *Chamaedaphne calyculata*, *Andromeda glaucophylla*, *Alnus incana*, and *Rosa carolina* are the dominant plants. Other plants are: *Sarracenia purpurea*, *Kalmia polifolia*, *Sphagnum spp.*, *Menyanthes trifoliata*, *Larix laricina*, *Calopogon pulchellus* (Sw.) R. Br., and *Picea mariana* (Mill.) BSP. At the southern tip of this zone a large bed of *Nymphaea advena* borders the mat. Just back of the Nymphaea, *Decodon verticillatus* (L.) Ell. is the principal plant at the edge of the mat. Throughout this zone, in a mat made up largely of Sphagnum, branches of Chamaedaphne, Andromeda, and Rosa extend out over the water and roots appear to develop at nodes on the submerged portion of the stems. Tamarack and spruce are both found at the water's edge.

Zone 2 is indicated on the map as Chamaedaphne scrub, which covers the remainder of the quaking mat. In this zone numerous plants grow. Tamarack and spruce are abundant, but are so scattered that they offer little if any shade. The chief plants in this zone are: *Chamaedaphne calyculata*, *Andromeda glaucophylla*, *Kalmia polifolia*, *Calopogon pulchellus*, *Pogonia ophioglossoides* (L.) Ker., *Habenaria blephariglottis*, *Eriophorum spp.*, *Vaccinium Oxycoccus*, *Drosera rotundifolia*, *Menyanthes trifoliata*, *Sarracenia purpurea*, *Sphagnum spp.*, *Xyris caroliniana* Walt., *Aspidium spinulosum*

(O. F. Müller) Sw., *Chiogenes hispidula, Eriocaulon articulatum* (Huds.), *Rynchospora alba* (L.) Vahl., *Habenaria clavellata* (Michx.) Spreng., *Eleocharis spp., Larix laricina, Picea mariana,* and *Picea canadensis* (Mill.) BSP.

The portion of the bog which may be classed as mature is indicated as Zone 3. It lies just west of the "ice-shove ridge," a sandy ridge that apparently prevents flooding during the high water stages of the lake. It is firmly grounded and is so heavily shaded that ground cover of herbs and shrubs is sparse as compared with the vegetation in Zone 4.

On this mature mat there is a rather heavy stand of beech, hard maple, red maple, and serviceberry, and, occasionally, white oak and white pine. The ground plants include blueberries (*Vaccinium spp.*), *Coptis trifolia* (L.) Salisb., bracken, wintergreen, *Corallorrhiza trifida* Chatelain, *Cornus canadensis* L., *Cypripedium acaule, Woodwardia virginica, Monotropa uniflora* L., Sphagnum locally, *Melampyrum lineare* Lam., *Osmunda cinnamomea,* and *Aspidium Thelypteris* (L.) Sw.

In Zone 4 there is a heavy stand of tamarack and spruce. These trees are on the firmer portions of the mat and have produced such dense growth that Sphagnum has been almost completely shaded out, as have been many of the other plants associated with Sphagnum. In this entire zone Chamaedaphne persists as the dominant mat covering. Locally small hummocks of Sphagnum may occur with *Vaccinium Oxycoccus, Chiogenes hispidula,* and a dwarf blueberry (*Vaccinium sp.*). *Cypripedium acaule* Ait. is common in the dense shade under the large spruces.

The northern dwarf mistletoe (*Arceuthobium pusillum* Peck) is widely distributed on spruce in Zones 1, 2, and 4, but not on spruce that occurs on the drier portions of the mat in Zone 6. Although the host trees were heavily infected, no noticeable disturbance to growth was apparent other than occasional "witches'-brooms" on some of the taller trees.

Beyond the zones of trees, toward the cultivated uplands, is a region of pure stand Chamaedaphne. In this zone all the smaller ground plants appear to have been replaced by Chamaedaphne which thrives wherever it occurs on the mat.

At the southern tip of the larger area in Zone 5 a small waste section is covered with weeds and swamp grass. This has resulted

from cutting during the harvesting of hay on the uplands. In the uplands to the north of the bog the forest of second-growth hardwoods is largely made up of hard maple and beech, with an occasional *Populus grandidentata* and *Prunus virginiana*. *Amelanchier canadensis* appears nearer the edge of the mat. On the edge there is a shrub zone in which *Ilex verticillata*, *Nemopanthus mucronata*, *Pyrus arbutifolia*, and *Salix spp.* are the principal shrubs.

Two regions on the mat with no spruce are indicated in Zone 6. In them Chamaedaphne occurs in almost pure stand. Tamaracks were once widely distributed, as is shown by the large number of dead trees still standing. Many were killed by the larch sawfly in 1930.

Throughout Zone 6 the heavy stand of Chamaedaphne is broken only by rather widely scattered tamaracks and spruce. The trees are small and do not show the luxuriant growth manifested by spruce in Zones 1, 2, and 4.

In July, 1941, a number of borings were made on the mat. The maximum depth of peat was 25 feet 4 inches at a point about 800 feet to the southwest of the north end of the "ice-shove ridge" and about 175 feet in from the edge of the lake. About midway between this boring and the center of Zone 4 the greatest depth of peat was 10 feet. A boring some 150 feet farther to the southwest showed the depth of peat to be only two and one-half feet.

All borings except one indicated that peat was deposited on sand. At the point where peat was bored to its greatest depth the upper 12 to 16 feet of the mat was rather firm and yielded cores of peat, but the lower 8 to 10 feet produced only an unsolidified mass, with no deposition of peat on the sand bottom.

3. EDGEWATER BOG

Location

The Edgewater Bog (Fig. 3) is located along Highway M–22 about one-eighth mile east of the Platte River bridge in Benzie County. It lies in almost the center of Section 27 of Lake Township, R. 86 W. and 15 N. It is situated between two sand ridges, one of which separates the bog from the Platte River to the south. Lake Michigan lies just a mile to the north, and the intervening area is made up of a series of sand ridges that parallel the shores of the lake.

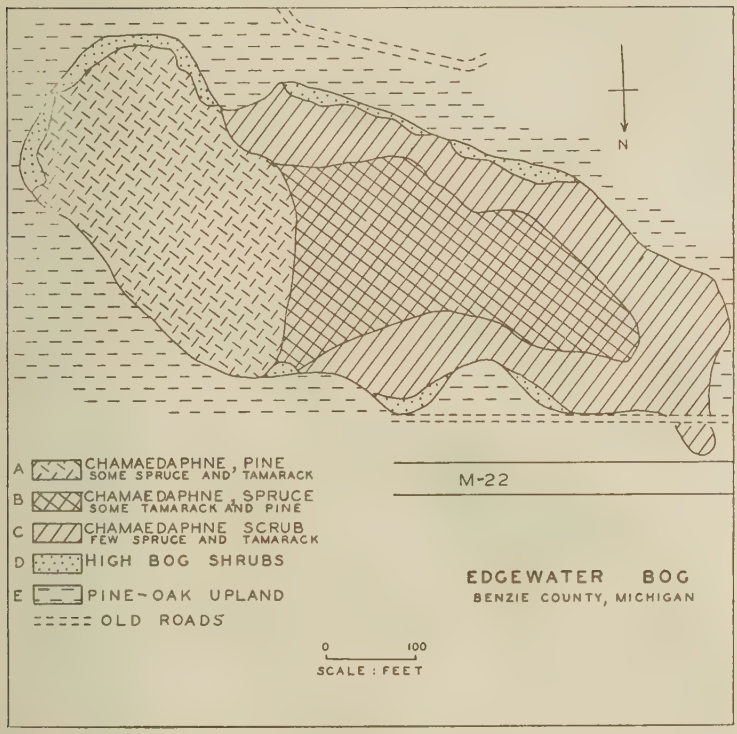

Fig. 3

The bog is roughly 850 feet in length, with an average width of about 300 feet. The longest axis is in an east-west direction. It covers an area of between five and six acres and is easily accessible at any point of its periphery.

Geological Features

The region in which the bog is located was once a great bay in Lake Algonquin, the site of which is now occupied by a series of sand ridges with depressions between, known as the Platte Plains (Waterman, 1917, 1922a, 1922b). This area may be described as a right-angled triangle, the base of which extends east and west eight miles and the east side about the same distance north and

south. The hypotenuse is formed by the shoreline of Lake Michigan from the moraine south of Empire to a point almost three miles northwest of Point Betzie. Between the sand ridges and the Algonquin bluff is a wide crescent-shaped trough of relatively slight depth containing a series of lakes or ponds more or less connected with and draining into the Platte River, which meanders through the sand ridges and reaches Lake Michigan about the center of the hypotenuse of the right-angled triangle. From east to west these lakes are Long Lake, Rush Lake, Platte Lake, and Little Platte Lake. On the east three small lakes are connected by Otter Creek.

There are two small lakes, Loon Lake and Mud Lake, on the lower stretches of the Platte River. When the glaciers were finally melting and opening the Straits of Mackinac, the waters of Lake Algonquin gradually receded and formed a series of sand bars with lagoons between them. On these bars the winds have built up low dunes, which now constitute the sand ridges of the Platte Plains. The larger depressions remain as lakes, but the smaller ones have been more or less filled by the growth of aquatic vegetation.

Early History

The bog is appropriately named "Edgewater Bog," for during the lumbering days a logging community was established along the Platte River about where the present Highway M–22 crosses the river. When lumbering operations ceased, the community disappeared, although the name "Edgewater" still appears on the maps of the region.

In many areas of the Platte Plains the vegetation has been influenced by local fires in prelumbering days (Waterman, 1917). The region in which the bog is located appears to have been disturbed only by logging operations. Whether or not any large trees were removed from the bog is not known.

Floristics and Zonation

The zonation of the vegetation on this bog is less distinct than that on any of the other bogs studied. Zones A, B, and C, as shown in Figure 3, grade into one another almost imperceptibly, the most noticeable difference in the zones being perhaps the somewhat less frequent occurrence of spruce and the smaller size of trees in Zones B and C than in Zone A.

In Zone A there is a heavier stand of conifers, white pine, red pine, tamarack, and spruce. The dense stand of Chamaedaphne appears to be giving way to trees that are now producing heavy shade. Sphagnum is found locally in small hummocks, accompanied by *Vaccinium Oxycoccus, Sarracenia purpurea,* and *Drosera rotundifolia.* It appears to be dying out wherever it occurs on the mat.

In the more heavily shaded portion of this zone, to the east, the principal ground plants that are becoming established in areas where Chamaedaphne has been killed are: *Pteris aquilina, Gaultheria procumbens, Eriophorum spp.,* Polystichum and Polytrichum moss, and blueberries (*Vaccinium spp.*). *Cypripedium acaule* occurs under the larger pines.

The east end of the mat also shows invasion of trees from the upland such as *Quercus alba* L., *Acer rubrum, Populus grandidentata,* and *Betula papyrifera.*

The vegetation in Zone B differs only slightly from that in Zone A. The conifers are not so densely distributed since spruce is slightly less abundant, and it is smaller. Chamaedaphne, however, makes a heavy and luxuriant growth in this zone, with fewer areas in which it has been killed, apparently by shade. Sphagnum is the only plant found locally with *Vaccinium Oxycoccus* and *Chiogenes hispidula.*

Zone C is a narrow zone in which the conifers are slightly less abundant than in either Zone A or Zone B. In it Chamaedaphne is vigorous and occurs in almost pure stand, and Andromeda appears only occasionally here and also on other parts of the mat. Beside the highway and along the west margin of the mat the upland trees are invading the mat, the principal species being white oak and large-toothed aspen.

Zone D is the zone in which the high-bog shrubs grow on the mat. It is narrow but quite extensive along the south and southwest margins of the mat. At the north margin these shrubs occur only in three small clumps. The principal shrubs in this zone are: *Nemopanthus mucronata, Pyrus arbutifolia, Ilex verticillata, Hamamelis virginiana* L., and *Salix spp.* Arbor vitae and spreading junipers grow in clumps along the north margin.

The mat has become quite firm. The Chamaedaphne stage is apparently giving way to the bog forest, which at present is made

up chiefly of red pine, white pine, tamarack, and spruce. In the more mature Zone A upland trees are rapidly invading the mat, as they are in Zone C at the west end. *Picea canadensis* is occasionally found in Zones A and B.

The surrounding upland has a vegetation typical of the sand ridges of the Platte Plains. The dominant plants of the ground cover are: *Pteris aquilina, Gaultheria procumbens, Epigaea repens* L., *Campanula rotundifolia* L., *Arctostaphylos Uva-ursi* (L.) Spreng., and blueberries (*Vaccinium spp.*). Among the trees characteristic of this area the most important are: *Quercus alba, Acer rubrum, Populus grandidentata, Prunus virginiana,* and *Amelanchier canadensis.*

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ADDITIONS TO THE MYCOLOGICAL FLORA OF THE CHICAGO REGION

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THREE authors have previously reported on the agarics to be found in and about Chicago, Illinois. In 1909 Moffatt (5) listed 210 species; in 1927–33 Graham (1–3) added 46; and in 1936–40 Routien (6–7) increased the number by 41. In the summer of 1940 the present author collected 115 species of agarics in a small part of this same area. Of these species 43 had not hitherto been published as being from this region. The total of agarics for the Chicago region is now 48 genera, 339 species, and 18 varieties.

The genera with the greatest number of species are: Hygrophorus, 24; Russula, 22; Collybia, 21; Marasmius, 20; Lactarius, 19; and Clitocybe, 17. There are, in addition, 6 varieties of Hygrophorus and 2 of Clitocybe. From the author's observations, however, the genera most dominant in the number of fruiting bodies appear to be Hypholoma and Coprinus.

The increase in the number of species is evidently due to each author having limited his collecting to places readily accessible to him and not studied by the others. In this way each worker collected under different conditions and found different species. To suppose that the new species were introduced by natural agencies seems illogical because the areas that are favorable for the growth of agarics are isolated from one another by fields and urban districts. Most of the author's collections were made in a wood along the Des Plaines River, an area of not more than twelve acres.

In his paper Moffatt (5) wrote: "The region at the head of Lake Michigan is by no means an ideal one for the collector." Graham (3) estimated that there were at least 700 species of mushrooms (using the term in a broad sense). As already stated, there are known to be at least 339 species of agarics alone in this limited area. The fact that there have been found at least one third as many agarics as Kauffman (4) listed for Michigan, in addition to a great diversity of

other fungi in the larger wooded localities, does not uphold Moffatt's assumption.

In general, the species from the Chicago region correspond with the descriptions given by Kauffman. However, thirteen of these species were larger, on the average, in size of pileus, stipe, or spores, and eighteen were smaller in some structure. In spite of these minor, though constant, differences, the Chicago species were evidently the same.

The present additions to the agaric flora of the Chicago region are: *Agaricus subrufescens* Pk., *Amanitopsis vaginata* (Fries) Karst. var. *alba* Sacc., *Clitocybe candida* Bres., *C. pulcherrima* Pk., *Collybia cirrata* (Fr.) Quél., *C. colorea* Pk., *C. hariolorum* (Fr.) Quél., *C. lentinoides* Pk., *C. longipes* (Fr.) Sacc., *C. myriadophylla* (Pk.) Sacc., *Coprinus arenatus* Pk., *C. sterquilinus* (Fr.) Quél., *Crepidotus haerens* (Pk.) Sacc., *C. versutus* (Pk.) Sacc., *Entoloma indigoferum* (Ellis) Sacc., *Galera lateritia* (Fr.) Quél., *Hebeloma capnoides* (Fr.) Quél., *H. saccharinophilum* Pk., *Inocybe longicystis* Atk., *Lentinus vulpinus* Fr., *Lepiota rugulosa* Pk., *Marasmius foetidus* Fr., *M. graminum* (Libert.) Berk. & Br., *Mycena lasiosperma* Bres., *M. polygramma* (Fr.) Quél., *Naucoria lignicola* (Pk.) Sacc., *Omphalia lutcola* Pk., *Panaeolus campanulatus* (Fr.) Quél., *Panus angustatus* Berk., *Pholiota discolor* (Pk.) Sacc., *P. duroides* Pk., *P. squarrosoides* (Pk.) Sacc., *Pleurotus petaloides* (Fr.) Quél., *Pluteus longistriatus* (Pk.) Sacc., *Psilocybe agariella* Atk., *P. atrorufa* (Fr.) Quél., *P. murcida* (Fr.) Karst., *Russula albida* Pk., *R. lepida* Fr., *R. subdepallens* Pk., *R. uncialis* Pk., and *Tricholoma resplendens* Fr.

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MARINE ALGAE OF HONG KONG. V
THE GENUS HERPOSIPHONIA *

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THE genus Herposiphonia was proposed by Nägeli in 1846 in a paper dealing with the morphology of two plants of this group. Curiously, no specific names were mentioned in the entire article. Nevertheless the illustrations and the very detailed descriptions show without the least doubt that the species Nägeli had in mind in proposing the genus were *Hutchinsia tenella* C. Ag. (*Polysiphonia tenella* (C. Ag.) J. Ag.) and *Hutchinsia secunda* C. Ag. (*Polysiphonia secunda* (C. Ag.) Zan.), the first of which has since been practically accepted as the type species of the genus. It should be noted here that in 1845 Kützing had already used the same name, Herposiphonia, for sections of the genus Polysiphonia, and that J. Agardh employed it later, in 1863. The section Herposiphonia of Kützing is different from that of J. Agardh, however, as well as from the genus Herposiphonia of Nägeli. The two species mentioned above also belong to the section Herposiphonia in the Kützingian classification, but are not included in the Herposiphonia section of J. Agardh. The latter phycologist seemed to disagree with Nägeli in placing them in a special genus separate from Polysiphonia, and he preferred to group them together with several others that we now recognize as members of Herposiphonia Näg., in the subsection Pectinatae of the section Ptilosiphonia of the genus Polysiphonia.

The combinations *Herposiphonia tenella* and *H. secunda* were first used by Ambronn in 1880. Several years later Schmitz transferred to Herposiphonia *Polysiphonia prorepens* Harv. and Okamura *Polyzonia fissidentoides* Holmes. In his monograph of the family Rhodomelaceae Falkenberg (1901) transferred eleven other Polysiphonia species to this genus, including a doubtful one that was subsequently removed. De Toni transferred three more species to it,

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all doubtfully. Later Pilger (1911, 1920) added two new species, and Okamura, Howe, and Gardner each added one. This is a total of twenty-two species of Herposiphonia, including three whose affinity with the genus is not definitely fixed. Two more species will be described in this article.

Plants of this genus are characterized by a creeping filamentous dorsiventral axis, sending stout vigorous rhizoids downward, long shoots laterally, alternately and horizontally, and erect subdorsal dwarf shoots in two rows, which are seldom strictly dorsal. A typical member, for instance, *H. tenella* (C. Ag.) Ambr., has the arrangement of its shoots repeated on the following pattern: a long shoot at the left, lateral, then a dwarf shoot on the second segment at the right subdorsal, another on the third at the left subdorsal, still another on the fourth at the right subdorsal, and then, on the fifth segment, another long shoot laterally at the right side. The long shoots are the branches; eventually they come to resemble the main axis and are indefinite in growth. The dwarf shoots are the branchlets and are definite in growth, finally giving rise to the reproductive organs. The apices of the axis and the horizontal branches are always more or less inwardly curved, and the growth is exogenous, the apical cell dividing transversely or slightly obliquely. The filaments are distinctly segmented, and the pericentral cells are numerous, ranging from 8 to 18, and naked, not covered by any corticating cells or filaments. The trichoblasts are deciduous or persistent, being quite simple or repeatedly subdichotomously branched. The tetrasporangia are formed in long single series in the middle part of the dwarf shoots. The spermatangial clusters are subcylindrical, replacing the trichoblasts on the dwarf shoots, and are spirally disposed at the distal ends. The subspherical, ovate, or urceolate cystocarps are solitary or in pairs, lateral near the apices, or subterminal on the dwarf shoots.

Members of this genus are inhabitants of the warmer waters, being especially abundant in the Australian and Indo-Pacific regions. None has so far been recorded from the Hong Kong area, although two have been reported from near-by Amoy (Tseng, 1936). Briefly, the characteristics that are employed in the identification and classification of the species of this small genus are: the habit and size of the plant and its filaments, the branching, the number of the pericentral cells, the length of the segments, the number of segments in

the dwarf shoots, the spermatangial clusters and their disposition, and the shape, size, and position of the cystocarps.

The four species now found in this region may be distinguished from one another by the following key:

A. Dwarf shoots branched above; number of pericentral cells 12–18 ..... 4. *H. ramosa*

A. Dwarf shoots simple; number of pericentral cells 8–12

B. Frond more rigid, with certain segments bare; long and dwarf shoots rather irregularly disposed ..... 3. *H. insidiosa*

B. Frond more flaccid, all segments with branches or branchlets that are very regularly arranged

C. Frond beautiful pinkish red, habit loose, epiphytic on other algae; dwarf shoots with 12–14 segments ..... 1. *H. Pecten-Veneris*

C. Frond dark purplish, forming dense pulvinate tufts, generally on rocks; dwarf shoots with 20–30 segments ..... 2. *H. caespitosa*

1. *Herposiphonia Pecten-Veneris* (Harv.) Falk.

Rhodomelaceen, 1901, p. 315; Howe, Bahama Alg., 1920, p. 573.
Polysiphonia Pecten-Veneris Harv., var. a Harv., Nereis Boreali-Americana, II, 1853, p. 46, pl. 16 C.

Frond small, delicate, beautiful pinkish red, loosely epiphytic on various algae; about 3 cm. long, patently and alternately decompoundly branched, with a branch or branchlet from every segment. Primary filament giving rise to both the dwarf and the long shoots, with three of the former between every two of the latter in the typical Herposiphonia pattern. These are arranged in four rows, two lateral, alternate rows of long shoots and two dorsal ones of the dwarf shoots. Main axis 120–150 μ in diameter, with segments 1.5–2.0 times as long as broad, attached to the host by long rhizoids of about 30 μ in diameter, each separated by a transverse wall from the mother pericentral cell, more or less flexuous, with its apex strongly and gracefully recurved, which results in its dorsal convexity. The long shoot, when fully mature, similar to the main axis in size, in the strong incurving of the tip, in the creeping habit, and in the indefinite growth. The dwarf shoot definite in growth and erect, 50–80 μ in diameter, and up to 1.0 mm. high, obtuse at the tip and rather strongly curved toward the axis. Each branchlet with 12–14 segments, which are slightly longer than broad below and shorter above. Trichoblasts present at the tips of the younger dwarf shoots, deciduous. Pericentral cells ranging from 8 to 12 in each segment. No reproducing specimens secured.

Habitat. — On other algae in the littoral region, Shaukiwan in May (*Tseng 345*) and Shek-O in March (*Tseng 649*), both on Hong Kong Island.

Distribution. — Key West, Florida (type locality), and the West Indies.

The present species, so far as its records show, has not been formally reported outside the Florida–West Indies region. Nevertheless, the writer has reasons to believe that it is quite extensively distributed. The difficulty in defining its distribution lies in the controversy whether it should be treated merely as a form of the more widely distributed *H. tenella* (Ag.) Ambr. or kept as a separate species. Falkenberg (1901) feels rather uncertain in regard to this question. American phycologists, Collins, Howe, and Taylor, have separated the two, whereas Børgesen seems to prefer to keep the plant under *H. tenella*, although he never did formally put Harvey's species as a synonym of the former. To judge from Okamura's description and illustrations (1930, p. 23, pl. 264, figs. 1–9) he has evidently adopted the same broad view of *H. tenella* that Børgesen did and included this species under the former. In the past the present writer also shared the view of Børgesen and Okamura and identified a similar alga from Amoy with *H. tenella* (Tseng, 1936, p. 59, pl. 6, fig. 36). Now, having studied many specimens of these two species from various places, he has come to agree with the American phycologists in keeping them separate and in differentiating the present species from *H. tenella* on the basis of its strongly incurved tips with dorsal convexity, its much shorter dwarf shoots with, as a rule, not more than fourteen segments each, and, consequently, its fewer sporangia, generally 4–7 in a series. Unfortunately, the cystocarps and spermatangial clusters, which would facilitate further comparison, are not known for both species. When found, they will surely help in solving the problem.

2. **Herposiphonia caespitosa**, sp. nov.

(Plate I)

Frons fuscipurpurea, mollis, dense pulvinata, caespitosa, repens, ca. 3 mm. alta, lateraliter decomposite ramosa; filamentis omnino sine cortice, 8-12-siphoniis, apice ascendentibus, articulis omnibus ramiferis, dispositione ramorum 4-seriata, ramis longioribus laterali-

ter, ramis nanis subdorsaliter dispositis; filamentis primariis et ramis longioribus decumbentibus dense radicantibus, dorsiventralibus, ad 200 μ (generaliter 120–150 μ) latis, articulis omnibus isodiametientibus vel brevioribus quam latioribus; ramis nanis subterctibus, erectis, ca. 3 mm. altis, 90 μ latis, apice obtusis vel rotundatis, articulis 20–30, isodiametris vel duplo longioribus quam brevioribus; trichoblastis 5- vel 6-plo dichotome ramosis, copiose ad apicem ramorum nanorum spiraliter ordinatis; tetrasporangiis ca. 35 μ latis, in medio ramorum nanorum spiraliter et uniseriatim ortis; cystocarpiis maturis urceolatis usque ad 460 μ latis, 520 μ longis, ut videtur in ramis nanis terminalibus, sed vero ab initio quasiterminalibus; acervulis spermatangialibus numerosis (10), subcylindricis usque ad 45 μ latis, 170 μ longis, superne cellula sterili praeditis, sed ad apicem ramorum nanorum spiraliter (uno in quoque articulo) dispositis. Species *Herposiphoniae prorepenti* (Harv.) Schmitz et *H. densae* Pilg. proxima.

Specimen typicum: *Tseng 2752* (in herbario auctoris), ad rupes zonae inferioris littoralis, prope Putoi Island, 22 Apr., 1940.

Frond flaccid, dark purplish, forming densely pulvinate tufts to about 3 mm. tall, laterally fastigiately decompoundly branched, with ecorticate filaments consisting of 8–12 rows of pericentral cells. Long and dwarf shoots disposed in four rows, as typical in the genus, with two lateral rows of long shoots and two subdorsal ones of dwarf shoots, and a branch or branchlet on each segment, hence always three dwarf shoots between the two alternating long shoots (Pl. I, Fig. 1). Primary filament and long shoots decumbent, dorsiventral, with their apices upwardly incurved, densely beset with stout unicellular rhizoids, which are generally in pairs, sometimes one or three to each segment, and up to 200 μ, generally 120–150 μ in diameter, with segments shorter than broad or subequal. Dwarf shoots subcylindrical, erect, up to 3 mm. tall, 90 μ in diameter, broader below, attenuated upward, sometimes to as much as 1.8 mm., long when mature, obtuse-rounded at the tips, and composed of 20–30 segments, which are longer below, to about twice longer than broad, and shorter above. Trichoblasts well developed, abundantly spirally disposed at the distal ends of the dwarf shoots, 5–6 times subdichotomously branched with a large basal cell about 20 μ in diameter. Chromatophores of the cells short and linear, transversely zonately arranged, giving the cells a striate appearance. Young tetrasporangia, about

35 μ in diameter, found only once, in the middle portion of a dwarf shoot in a single spiral series of nine (Pl. I, Fig. 4). Spermatangial clusters abundantly formed at the upper ends of dwarf shoots, subcylindrical, each terminating in a large sterile cell, about 45 μ broad and 170 μ long (Pl. I, Fig. 3), spirally arranged, replacing the trichoblasts and, because of the short segments there, very much crowded. When young, they are only about 200 μ long, but grow progressively with the branchlets and increase in number to 10–12, the male shoots maturing to a length of about 1 mm., about half or two thirds the length of the surrounding sterile shoots. Cystocarps subglobular to ovate at first, becoming more or less urceolate, to 460 μ in diameter, 520 μ long, including a neck of about 60 μ (Pl. I, Figs. 1-2), apparently terminal and generally solitary on each fertile shoot, the cystocarps occasionally occurring in terminal pairs, but one always larger and the other smaller and forming later (Pl. I, Fig. 2). Female branchlets are generally 0.75–1.0 mm. They are often only about one third to one half the length of the neighboring sterile filaments. Their segments, of the same number as those of the sterile filaments, are necessarily very much shortened.

Habitat. — On surf-beaten rocks in the lower littoral region, Shek-O, Hong Kong Island, in March and July (*Tseng 2661*) intermingled with *Taenioma* and other algae, and on Putoi Island, in April (*Tseng 2752*, TYPE).

The present species is unique among species of Herposiphonia in the at least apparently terminal position of the cystocarp. The cystocarps seem to be lateral in origin, just as they are in other species of the genus. This is inferred from the frequent occurrence of a small, inconspicuous protrusion near the base of some of them, which may represent the original apices of the female shoots, whose growth has been inhibited by the growth of the cystocarps (Pl. I, Fig. 2). In this respect there seems to be a gradual reduction of the active growth of the apex of the fertile dwarf shoot, from typical species like *H. secunda* through smaller species such as *H. prorepens* and *H. densa* to the present species. In the first species the apex of the shoot remains very active after the formation of the cystocarp, and sometimes even grows out to produce other dwarf shoots just like ordinary long shoots (Falkenberg, 1901, pl. 3, fig. 2, and Børgesen, 1920, p. 474, fig. 431 a, b). In the second one the growth of the apex is not so vig-

orous, but it still outgrows the cystocarp (cf. Harvey, 1862, pl. 185 B, figs. 2–3). In the third the activity of the apex has been reduced, and the cystocarp outgrows the apex of the fertile shoot, which, however, still remains distinct although short (cf. Pilger, 1911, fig. 17). In the present species the growth of the cystocarp is so rapid that the growth of the apex of the fertile shoot is entirely stopped; the apex is reduced to a very small, inconspicuous pseudolateral protrusion or, more frequently, is entirely aborted (Pl. I, Figs. 1–2).

This species is undoubtedly most closely related to *H. densa* from Africa which, as has been mentioned, has the fertile apex of the fertile branchlet very much reduced. They resemble each other in the dwarf, dense caespitose habit, the arrangement of the branches, the number of the pericentral cells, and the short segments. The main differences between the two lie chiefly in the position of the cystocarps, as noted above, and the much taller erect branchlets of the African plant (7–8 mm. as against 2–3 mm. in the present species). The striated closely transversely parallel arrangement of the short linear chromatophores seems to be quite characteristic of the Hong Kong plant, but is not reported for the African alga. *H. prorepens* is very closely related to these two species, but it is a much more delicate plant. The diameter of the axis and the branches is less, as are the height of the dwarf shoots and the number of segments. The sterile and fertile shoots are of about the same height.

3. *Herposiphonia insidiosa* (Grev.) Falk.

Rhodomelaceen, 1901, p. 317; Okamura, Icones of Japanese Algae, VI (3), 1930, p. 35, pl. 264, figs. 10–16; Tseng, Mar. Alg. Amoy, 1936, p. 60, pl. 6, fig. 34; Børgesen, Contrib. South Indian Marine Algal Flora, II, 1937, p. 352, fig. 18.

Polysiphonia insidiosa Grev. in J. Agardh, Species algarum, II (3), 1863, p. 926.

Frond fragmentary, only about 1 cm. tall, up to 120 μ in diameter in the main filaments and 80–90 μ in diameter in the branchlets, with well-developed rhizoids and segments much shorter than broad, to subequal; pericentral cells 8–12, sometimes slightly spirally twisted; branches and branchlets irregularly disposed, by no means like such typical species as *H. tenella* and *H. Pecten-Veneris*. The apices of the main filament and the long shoots upwardly curved, irregularly produced, often with variable numbers of dwarf shoots between them, and the axis sometimes with occasional bare segments. Dwarf shoots

are more or less alternately disposed, very much curved toward the apex of the plant, and strongly inrolled in a spiral, with 20–26 segments, and obtuse apices. Trichoblasts generally absent or, if present, simple and unbranched. The tetrasporangia are up to 60 μ in diameter, in a single longitudinal series in the central part of the dwarf shoot. Other reproductive organs were not found.

Habitat. — Intermingled with Laurencia on littoral rocks, Big Wave Bay, Hong Kong Island, in May (*Tseng 2577*).

Distribution. — East Indies (type region); Ceylon; Amoy, China; Japan.

4. **Herposiphonia ramosa,** sp. nov.

(Plate II)

Frons nigrescentipurpurea, aliquantum rigida, ca. 7 mm. alta, lateraliter decomposite ramosa, repens, ramulis rhizoideis bi- vel tricellularibus ad algas alias adfixa; filamentis omnino sine cortice, 12–18-siphoniis, apice ascendentibus, ramis aliis longioribus lateraliter ordinatis, aliis nanis subdorsaliter ordinatis, articulis isodiametientibus vel brevioribus quam latioribus, normaliter articulo ramo nano praedito sequente articulum ferentem ramum longiorem et articulis plerumque 2 (sed interdum 3–4) nudis sequentibus eundem ramum nanum; filamentis primariis et ramis longioribus decumbentibus, radicantibus, dorsiventralibus usque ad 240 μ (generaliter 180–200 μ) latis; ramis nanis subteretibus, erectis, ramosis, usque ad 7 mm. altis, 120–150 μ latis, apice obtusis vel rotundatis, articulatis 30–40; trichoblastis 4- vel 5-plo dichotome ramosis, apice ramorum nanorum spiraliter ordinatis; partes aliae desunt. Species *Herposiphoniae secundae* (C. Ag.) Ambr. proxima.

Specimen typicum: *Tseng 2647a* (in herbario auctoris) ad Corallinam, cum Falkenbergia epiphyticum, in zonae inferioris litoralis, prope Stanley Bay, Hong Kong Island, 19 Jun., 1939.

Frond somewhat rigid, blackish purple, about 7 mm. high, decompoundly laterally branched. Main filaments and long shoots decumbent, dorsiventral and attaching to other, especially coralline, algae, with long 2- to 3-celled rhizoidal branchlets, about 30 μ in diameter, with 12–18 pericentral cells (Pl. II, Figs. 1, 3), the segments all shorter than broad, or subequal. Long shoots horizontal and lateral dwarf shoots erect and dorsal, a dwarf shoot always following a long shoot,

generally followed in turn by two, sometimes even three or four, segments that are naked, after which the long shoot again occurs, on the other side (Pl. II, Fig. 1). A peculiarity observed in this plant is the possession of branches on the dwarf shoots (Pl. II, Fig. 2), which branches issue exogenously and are irregularly subdichotomous or subpinnate. The dwarf shoot, supposedly definite in growth, thus resumes branching, resembling somewhat the main axis and the long shoots. The main filament and the long shoots are generally 180–200 μ, sometimes to 240 μ, in diameter. They have their apices upwardly incurved and segments shorter than, or subequal to, the diameter. The dwarf shoots are up to 7 mm. high, 120–150 μ, sometimes 180 μ, in diameter. They are obtuse-rounded at the tips and are composed of 25–50 segments, which are about as long as broad below, becoming longer, to 1.5 times longer than broad in the middle, and shortening again above. Trichoblasts are 4–5 times dichotomously branched, with basal cells to 20 μ in diameter and are spirally disposed on the distal ends of the dwarf shoots. Specimens collected are all sterile.

Habitat. — Epiphytic on corallines, together with Falkenbergia, in the lower littoral region, Stanley Bay, Hong Kong Island, in June (*Tseng 2647a*, TYPE) and Clear Water Bay, Port Shelter, Kowloon in May (*Tseng 2803a*).

The present species is unique among the members of the genus Herposiphonia in the possession of branches by the dwarf shoots. This characteristic and the large number of pericentral cells (12–18) as well as its brownish to blackish purple rather rigid frond remind one very much of *Lophosiphonia obscura* Auct. ex Howe. However, it cannot be referred to that species, or even to the genus Lophosiphonia, because of the exogenous growth and the regularity exhibited by the long and dwarf shoot sequence. Among other species of Herposiphonia probably the most closely related is *H. secunda*, which also has certain segments naked without any branch or branchlet and in which the number of segments between the two alternating long shoots sometimes varies between 3 and 5. From that species *H. ramosa* differs, not only in the branching of dwarf shoots, but also in the greater number of pericentral cells (12–18 against 8–12) and of segments in the dwarf shoots (25–30 against 7–20), and in the more robust frond (240 μ in diameter, against 150 μ).

SUMMARY

Of the four species of Herposiphonia reported in this article two are described here for the first time. *Herposiphonia caespitosa* Tseng, sp. nov., a species closely related to *H. densa* Pilg. from Africa, is unique in having apparently terminal cystocarps. *Herposiphonia ramosa* Tseng, sp. nov., a species more nearly related to the widely distributed *H. secunda* (C. Ag.) Ambr. than any others, is unique in having branched dwarf shoots. Of the two other known species, *H. Pecten-Veneris* (Harv.) Falk. of the Florida-West Indian region, generally confused with the widely distributed *H. tenella* (C. Ag.) Ambr., is here formally credited to the China coast for the first time, although it had been reported previously under the latter name from Amoy. *H. insidiosa* (Grev.) Falk., originally described from the East Indies, probably widely distributed in the Indo-Pacific region, has been reported from Amoy on the China coast.

The writer wishes to thank Professor Wm. Randolph Taylor, of the University of Michigan, for his advice during this study.

University of Michigan

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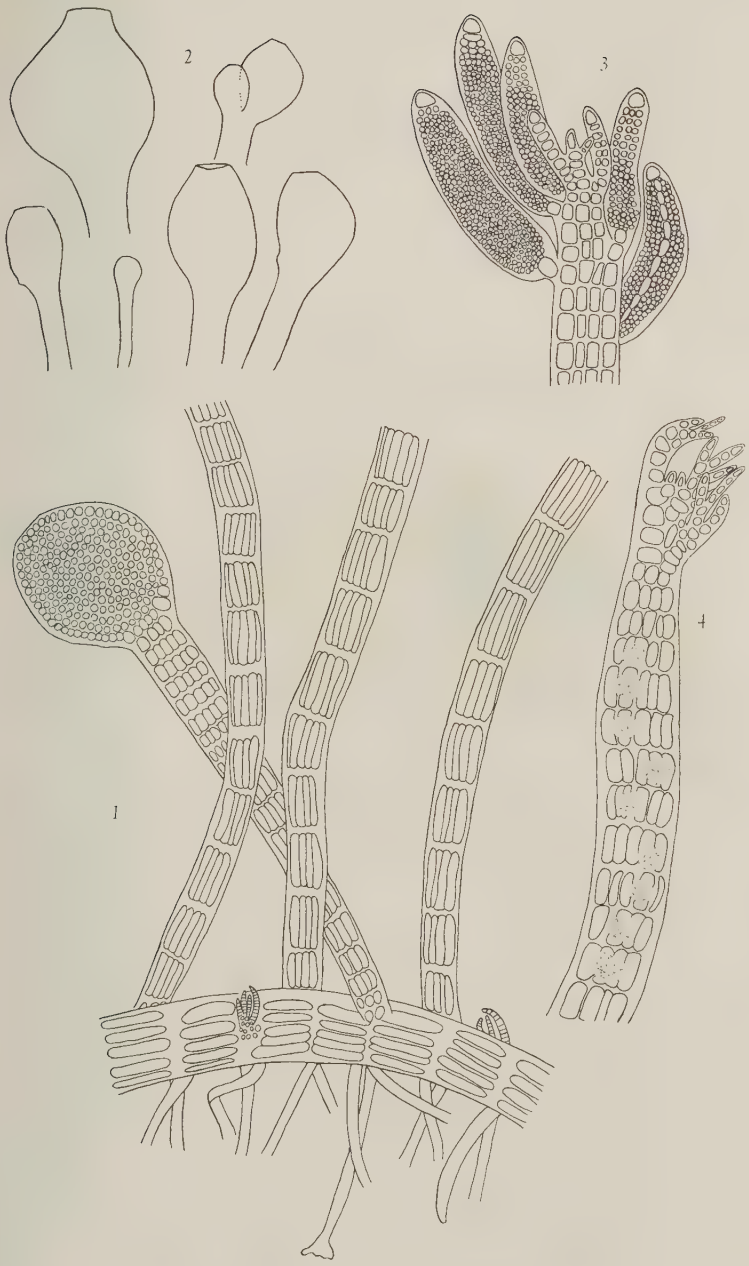
EXPLANATION OF PLATE I

FIG. 1. Habit sketch of portion of cystocarpic plant. × 83

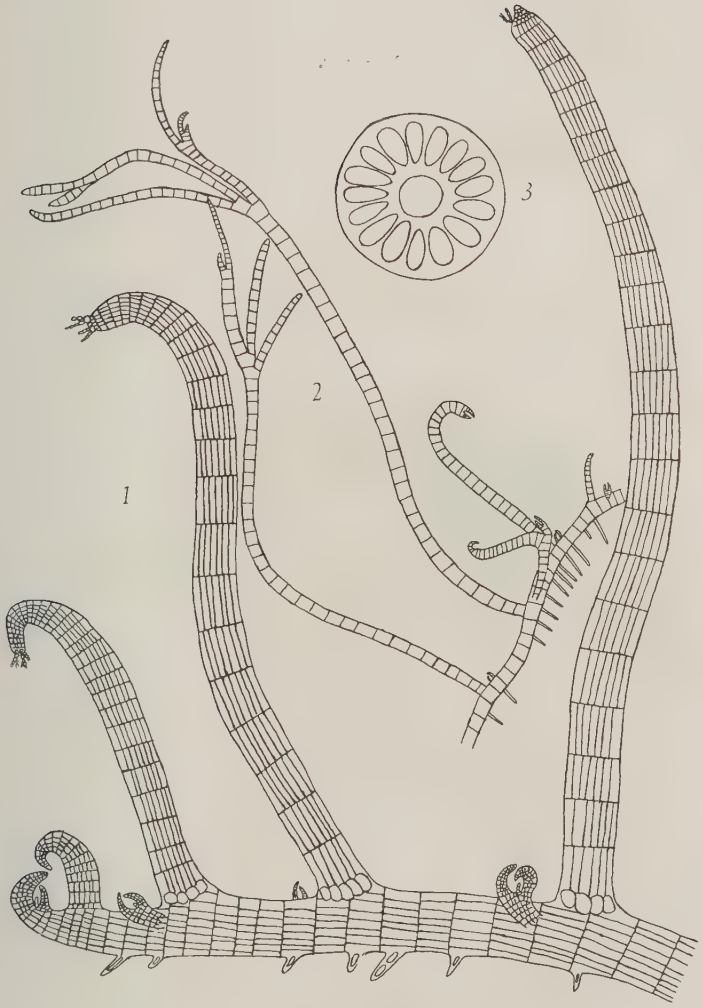
FIG. 2. Cystocarps in different stages of development, with two in pair. × 44

FIG. 3. Upper part of male branchlet, showing gametangial cluster. × 83

FIG. 4. Upper part of young tetrasporic branchlet, showing young trichoblasts. × 166



Herposiphonia caespitosa Tseng, sp. nov.



Herposiphonia ramosa Tseng, sp. nov.

Fig. 1. Habit sketch, showing general structure. × 57

Fig. 2. Habit sketch, showing branching of dwarf shoots. × 16

Fig. 3. Transverse section of branchlet. × 108

MARINE ALGAE OF HONG KONG. VI
THE GENUS POLYSIPHONIA *

CHENG KWEI TSENG

THE generic name Polysiphonia was proposed by Greville in 1824 as a substitute for Hutchinsia C. Agardh (1817) since the latter name was already preoccupied by a group of cruciferous plants, namely, Hutchinsia R. Brown (1812). Bonnemaison (1822) had already proposed the name Grammita for the ineligible Hutchinsia C. Ag., but Greville objected to it because of the possibilities of confusion with the generic name Grammitis, which had been used for one group of fungi and for another of ferns. Greville also overlooked the earlier published Vertebrata S. F. Gray (1821) referring to the same group of algae. Theoretically, therefore, Polysiphonia Grev. is a superfluous name and would be rejected if it had not been legalized in the status of a *nomen conservandum* by the International Botanical Congress (cf. Briquet, 1935, p. 88).

Plants of this genus are either entirely erect, rising from a more or less discoid holdfast, or with decumbent basal filaments, which attach to the substratum by a number of stout rhizoids originating from the pericentral cells, or, in corticated species, from the cortical cells. As a rule, the frond is abundantly dichotomously or laterally branched. The branches are filamentous, finely capillary to very coarse. Structurally the main axis and the branches of all orders are similar and polysiphonous, being composed of a series of axial cells surrounded by four to twenty-four rows of pericentral cells of similar length but generally of larger diameters. The pericentral cells are parallel to the central siphon; a few, however, are spirally twisted. In some species most of the frond, except the ultimate branchlets, is lightly or densely corticated by small cells or rhizoidal downgrowths that originate from the pericentral cells and may build up a pseudoparen-

* Papers from the Department of Botany of the University of Michigan, No. 825.

chymatous cortex. Trichoblasts, which usually are present, are deciduous or persistent, occurring as delicate colorless dichotomously branched filamentous hairs, near the tips of the branchlets; these are regarded by some as equivalent to "leaves."

Tetrasporangia are formed in the ultimate branchlets, generally near the tips, and are slightly or greatly swollen to distorted. They are solitary, one in each segment, and occur in straight or spirally twisted series. In the formation of these spores the fertile pericentral cell divides lengthwise, and the inner daughter cell divides again transversely, the upper one becoming the sporangium mother cell, which, by meiosis and tetrahedral cytokinesis, gives rise to the four tetrahedrally grouped tetraspores. The spermatangial clusters are colorless and ovoid to subcylindrical; each is transformed from an entire trichoblast, or a part of it, at the distal end of the branchlet. The fertile portion is polysiphonous, bearing on the pericentral cells the numerous small colorless oval spermatangia. Procarps are also developed from trichoblast rudiments. Cystocarps are typically urn-shaped, each having at the top an ostiole through which the numerous pear-shaped, or sometimes subglobose to ovate, carpospores are discharged.

Polysiphonia is one of the largest genera among the marine algae and, although many of its former members have been transferred to various other genera lately proposed, a few hundred species are still recognized in the genus. A great percentage of these presumably "valid" species may eventually be found to be synonymous with others when a critical revision of the genus can be made. Geographically the genus is a cosmopolitan one that is found in practically all the oceans and seas from the Antarctic to the Arctic. Generally speaking, the members in the warmer waters are more delicate ecorticate or lightly corticated tetrasiphonous species, whereas those of the colder waters are more robust, often corticated, and tetrasiphonous as well as polysiphonous.

Plants of this genus vary greatly in color, size, and habitats. They are found on rocks, sand, and mud, and in sheltered as well as exposed places. Some inhabit deep seas; others may occur only near high-water mark or far up the estuaries of tidal rivers. There are many epiphytic forms growing on various coarser algae.

The genus is divided into two sections, Oligosiphonia, with four pericentral cells, and Polysiphonia, with more than four. Further

division of the sections is based on the presence or the absence of the cortication. Other characteristics employed in the differentiation of the various species are: the method of branching, the nature of the attachment organs, the relative length of the articulation, the origin of the trichoblasts and of the branches, the nature of the tetrasporangial branchlet, the position of the spermatangial clusters, and the shape and size of the cystocarps.

The only record of Polysiphonia in the Hong Kong region is that of *P. Harlandii* Harv., described as occurring on materials collected from Hong Kong Island by "Charles Wright in the North Pacific Exploring Expedition under Captain John Rodgers." From other parts of the North China coast three more species have been reported, namely, *P. japonica* Harv., *P. urceolata* (Lightf.) Grev., and *P. Morrowii* Harv. Collins' record of "*P. ferulacea*" has been shown by Howe (1924, p. 141) to be based on a plant of *P. japonica* and should be taken from the floristic list of China. It is certainly incredible that there would be only four species of this large widely distributed genus on so extensive and varied a coast as that of China. The difficulty of delimiting the Polysiphoniae has probably discouraged reports of their occurrence. In fact, in the writer's own collections there are about two dozen species still waiting to be reported.

At least six species are now known to be represented in the flora of Hong Kong. Except for *P. Harlandii* Harv., originally described from this region, they are all recorded here for the first time from any part of China. The following key serves to distinguish them:

A. Frond corticated in the lower portion ..... 6. *P. Harlandii*
A. Frond ecorticate
  B. Filaments slender, not over 90 μ in diameter; rhizoids continuous with the mother pericentral cells; trichoblasts generally absent or, if present, poorly developed and deciduous ..... 1. *P. subtilissima*
  B. Filaments coarser, to 180 μ in diameter or more; rhizoids separated from the mother pericentral cells by cross walls; trichoblasts mostly present and well developed
    C. Frond solitary, epiphytic, small, to 1 cm. high ..... 3. *P. Savatieri*
    C. Frond in tufts on rocks, larger, 2 cm. or more high
      D. Frond regularly sparsely and distantly subdichotomously branched, to 180 μ in diameter ..... 2. *P. coacta*
      D. Frond profusely, closely alternately branched, to 250 μ or more in diameter
        E. Frond reddish purple, soft, segments generally as long as broad, pericentral cells elongated-rectangular, tetrasporangia forming elongated spiral series in the otherwise ordinary branchlets ..... 4. *P. gracilis*

E. Frond reddish brown (blackish when dried), rigid, segments generally half as long as broad, pericentral cells subquadrate, tetrasporangia in short series in special dichotomous branchlets, the fertile portion more or less swollen and distorted ..... 5. *P. ferulacea*

1. *Polysiphonia subtilissima* Mont.

(Plate I)

Pl. cell. cent., II, 1840, p. 199; Harvey, Ner. Bor.-Am., II, 1853, p. 34; Kützing, Tab. Phyc., XIII, 1863, pl. 28, figs. a–e; Farlow, Mar. Alg. New Engl., 1881, p. 170; Taylor, Alg. Northeastern Am., 1937, p. 365.

The present species forms dense purplish brown soft and flaccid, but nongelatinous tufts, about 2–3 cm. high. The frond is tetrasiphonous (Pl. I, Fig. 4) and ecorticate throughout, and consists of a horizontally running stoloniferous basal filament attaching to the substratum by stout rhizoids and giving rise to the erect branches upward at irregular intervals, almost perpendicularly (Pl. I, Figs. 1–2). The creeping filaments have thick walls and are sinuose, 60–75 μ in diameter, with segments about as long as broad. The rhizoidal filaments are about 45–60 μ in diameter and are merely modified pericentral cells; in other words, in the formation of the rhizoid the pericentral cell simply extends by lateral growth without forming another rhizoid-initiating cell, as it does in most other species. The cell contents of the rhizoids are therefore continuous with those of the pericentral cells. These rhizoids generally end in broad lobed discs (Pl. I, Fig. 2).

The erect branches are repeatedly subdichotomously branched below and alternately or sometimes unilaterally branched above (Pl. I, Fig. 1). The basal parts of these branches are of sizes similar to those of the stolon, 60–75 μ in diameter, with segments about as long as broad. Upward the diameter of the segments gradually decreases, but the length increases until they are about one and one-half times longer than broad. At the terminal part the segments again shorten a great deal, and are generally only about one third of the diameter long; the filaments there measure 20 30 μ in diameter. A large apical cell terminates the branchlet (Pl. I, Fig. 3). The trichoblasts are generally absent, although a few poorly developed ones are found. Most probably they are deciduous, and that may be why they are generally reported to be absent. The branches are lateral in origin, not subtended by the trichoblasts.

Only young tetrasporic plants were collected. The tetrasporangia, about 60 μ in diameter when mature, are in a straight, longitudinal series in the central portions of the ultimate branchlets, which are slightly swollen (Pl. I, Fig. 5).

Habitat. — On mud-covered littoral rocks in sheltered places, Shatin, Tide Cove, Kowloon; in May (*Tseng 2786*), intermingled with Caloglossa in April (*Tseng 2727a*) and Lophosiphonia in April (*Tseng 2754a*) and July (*Taam A144a*).

Distribution. — Cayenne, French Guiana, on northern South America (type locality), northward to Massachusetts; Africa.

The writer has hesitated to refer his plants to the rather imperfectly known *P. subtilissima*. The difficulty lies in the fact that the specimens collected from various places in the Americas and assigned by various phycologists to this species are probably heterogenous, consisting of more than one species. Consequently the writer has to select certain specimens out of the mixture and give to them the present specific name, basing his judgment, unfortunately, not on the type specimen, which is not available to him, but, rather, on the original description of Montagne, *loc. cit.*, supplemented by that of Harvey, *loc. cit.*, who claimed that he had studied one of the original specimens, and the little note by Howe (1920, p. 569). With these American specimens thus regarded as approaching typical *P. subtilissima* Mont., those from Hong Kong, cited above, agree very well.

2. **Polysiphonia coacta**, sp. nov.

(Plate II)

Frons fulvipurpurea, pulvinata, caespitosa, ca. 2 cm. alta; filamentis primariis decumbentibus radicantibus; ramis principalibus erectis, inferne hinc illinc inter se per tenacula rhizoidea adhaerentibus, parce distanterque subdichotome ramosis; filamentis subtetragonis, tetrasiphoniis, sine cortice, omnino articulatis, usque ad 180 μ latis, sursum attenuatis, ad apicem 30–40 μ latis; articulis omnibus isodiametientibus vel diametro brevioribus quam latioribus; ramis trichoblastorum locum tenentibus; tetrasporangiis ca. 45 μ latis, in superiore parte ramorum spiraliter ortis et in seriebus brevibus praesentibus; cystocarpiis (immaturis) ovatis, subsessilibus. Species *Polysiphoniae incomptae* Harv. proxima videtur.

Specimen typicum: *Taam A 62* (in herbario auctoris) ad rupes

arenosas zonae inferioris litoralis, prope Panglongwan, Port Shelter, 26 Mar., 1941

Plants of the present species form brownish purple pulvinate tufts about 2 cm. high. The primary filaments are decumbent, attaching to the substratum by producing downward short, stout rhizoids. The latter, to 70 μ in diameter, grow out from the pericentral cells, separating by cross walls, and end in broad adhesive discs, many of which usually adhere to one another and thus form a very effective attachment organ (Pl. II, Fig. 1). The erect filaments are sparsely and distantly subdichotomously branched, occasionally with some alternate or unilateral branchlets. The two arms of the dichotomy are unequally developed (Pl. II, Fig. 2). The lower parts of the erect filaments are so intricately and firmly united with one another by the rhizoids, acting as tenacula at places of contact, that it is impossible to isolate the individual filaments without breaking certain parts of them. The filaments are about 180 μ in diameter in the decumbent basal portions, gradually attenuating upward to 30–40 μ in diameter near the tips. In transverse section they appear somewhat tetragonal and are composed of four large pericentral siphons surrounding a small central one (Pl. II, Fig. 3). They are clearly articulate and ecorticate throughout. The segments are always shorter than broad, generally about half the diameter long in the lower parts to about as long as broad in the middle, and then shorter again to equal one third the diameter near the tips. The trichoblasts are well developed near the apices in a one-quarter divergence. The branches are nonaxillary, originating without reference to these trichoblasts. The tetrasporangia are about 45 μ in diameter and are spirally arranged in short series near the tips of the branchlets; the sporogenous portions are only slightly swollen. Some young cystocarps, about 120 μ in diameter, are found. They are ovate and subsessile (Pl. II, Fig. 4).

Habitat. — Abundant on sand-covered rocks in the lower littoral region, Panglongwan, Port Shelter, in March (*Taam A62*, TYPE).

The present species is probably more closely related to the Cape species, *P. incompta* Harv., than to others. That species is rather imperfectly known; it was described on sterile materials and is familiar to the writer only through descriptions. It is said to have the decumbent filaments with the longest segments to 1.5 times the diameter, gradually becoming smaller upward. The present species, on the

contrary, has much shorter segments in the basal filaments, longer ones in the middle and shorter ones again near the tips. In describing the African plant no mention was made of rhizoidal tenacula, which are characteristic of the Hong Kong alga. From other pulvinate-caespitose species of the ecorticate Oligosiphonia the present species differs in the characteristics mentioned above and also in the sparsely and distantly subdichotomously branched frond.

3. *Polysiphonia Savatieri* Hariot

(Plate III, Figure 1)

Alg. Mar. Yokoska, 1891, p. 226.

To this species is referred a smaller reddish epiphytic Polysiphonia. The frond is solitary, being only about 1 cm. high and is repeatedly alternately branched; the branches are subfastigiate and the branching more or less flabelliform. Owing to the vigorous growth of the side branches it sometimes appears to be dichotomous. The attachment to the host is by means of unicellular rhizoids, produced by and separated from the pericentral cells by cross walls. The filament is ecorticate and tetrasiphonous throughout, to 180 μ in diameter below, attenuating to 60–90 μ in diameter near the tips. The segments are distinct, shorter than broad near the base, soon becoming longer, to about 1.3 times longer than broad, and then gradually becoming shorter, to about half a diameter, long. The trichoblasts are 3–4 times dichotomously branched, spirally arranged near the tips in a one-quarter divergence. Young branches originate by replacement of the trichoblasts. The tetrasporangia, to 60 μ in diameter, form long single spiral series, to ten each, at the ultimate branchlets, extending from the tips downward to the third internodes (Pl. III, Fig. 1).

Habitat. — On Acanthophora, from Shek-O, Hong Kong Island, in May (*Tseng 2581a*); on Caulerpa, washed ashore, Clear Water Bay, Port Shelter, in February (*Taam A33d*).

Distribution. — Yokoska, Japan (type locality).

Since *P. Savatieri* Hariot was first described it has never been reported, not even from its "home," Japan, whose phycologists have been extensively investigating their algal flora for the last fifty years. The discovery of this little plant so far away from the type locality

without its having been previously reported from places in between is certainly of some interest. Possibly it is a common alga in the intervening area and has been overlooked by the collectors because of its small, rather inconspicuous frond. To be sure, the writer has not had the opportunity to study the type or any authentic specimens for comparison, and the species has never been illustrated. The identification of this alga must, therefore, be merely tentative. The type specimen, according to the original description, is cystocarpic. The tetrasporangia are here reported for the first time, if the determination be correct. Among the common species of Oligosiphonia *P. Savatieri* seems to be near to *P. ferulacea*, as Hariot, *loc. cit.*, pointed out. That species, however, is a much more robust plant in all respects, being entirely different in substance and color and having much shorter segments.

4. Polysiphonia gracilis, sp. nov.

(Plate III, Figures 2–3)

Frons rubripurpurea, ca. 6 cm. alta, mollis, gracilis, e filamentis decumbentibus assurgens; filamentis cylindricis, sine cortice, tetrasiphoniis, articulis; filamentis basalibus usque ad 450 μ latis, articulis diametro longitudineque subaequalibus, ad geniculas leviter incrassatis, rhizoideis substrato adfixis; filamentis erectis irregulariter lateraliter decompositis, articulis diametro sesquilongioribus vel subaequalibus, raro duplo longioribus; ramis ramulisque subfastigiatis, extra-axillaribus trichoblastorum locum tenentibus; tetrasporangiis usque ad 90 μ diam., in superiore parte ramorum ramulorumque ortis, in serie longa spiraliter ordinatis. Cystocarpia et acervuli spermatangiales ignota.

Specimen typicum: *Tseng 2723* (in herbario auctoris), ad rupes argillosas litoreas, prope Tsuenwan, Kowloon, 15 Apr., 1940.

This species has a reddish purple frond about 6 cm. high. It is soft and slender, arising from the decumbent filaments. The filaments are cylindrical, ecorticate, tetrasiphonous, and distinctly articulate throughout. The basal filaments, up to 450 μ in diameter, have segments about as long as broad, slightly thickened at the nodes, and attaching to the substratum by means of rhizoids, which are separated from the mother pericentral cells by cross walls (Pl. III, Fig. 3). The erect filaments are irregularly laterally decompound, with segments about as long as broad, or one and one-half diameters long, occasion-

ally to about twice as long as broad. The branches of all orders are generally subfastigiate and directed upward (Pl. III, Fig. 2). Occasionally, however, some of the young branchlets are rather patent and may even be slightly curved downward. Trichoblasts are in general very poorly developed at the tips of a few young branchlets; apparently they are deciduous since they are usually not observed. The branches and branchlets are evidently lateral in origin since they arise without apparent reference to the trichoblasts. All specimens collected are tetrasporic. The tetrasporangia are about 90 μ in diameter, forming an elongated spiral series in the upper portions of the branches and branchlets (Pl. II, Fig. 2). The fertile parts are not swollen or in any way distorted; they usually extend through several internodes, sometimes continuously, sometimes in several interrupted series. The youngest sporangia are generally found about a dozen cells below the apices of the fertile branches, which continue to grow and branch normally without being in the least distorted by the formation of the sporangia.

Habitat. — On mud-covered littoral rocks in sheltered places, Tsuenwan, Kowloon, in April (*Tseng 2723*, TYPE).

The present species is undoubtedly most closely related to *P. platycarpa* Borg. from India, differing from it chiefly in the much coarser filaments (about twice as large), the shorter segments (about half as long), and the absence or the poor development of the trichoblasts (very well developed in the Indian plant). Borgesen later strongly emphasized the close relationship of his plant with the Australian *P. mollis* Hook. f. et Harv., which has also been reported from Japan by Yendo and from the Malay Archipelago by Weber van Bosse, in both cases doubtfully. The Australian species, according to descriptions and illustrations by Kützing, appears to be a much more robust plant than both the Indian and the Hong Kong algae and, moreover, has a discoid holdfast that is not found in these two species.

5. *Polysiphonia ferulacea* Suhr ex J. Agardh

(Plate III, Figures 4–7)

Species algarum, II (3), 1863, p. 980; De Toni, Sylloge algarum, IV (3), 1903, p. 892; Collins and Hervey, The Algae of Bermuda, 1917, p. 124; Yendo, Alg. Jap., VIII, 1918, p. 75; Børgesen, Mar. Alg. Dan. W. Ind., II, 1920, p. 277, figs. 277–280, Ind. Rhodophyc., 1931, p. 16, figs. 10–11.

P. breviarticulata Harv., Ner. Bor.-Am., II, 1853, p. 36, pl. 16, B (non *P. breviarticulata* (C. Ag.) Zanard.).
? *P. fracta* Harv., *loc. cit.*, p. 38.
Forma **implicata**, f. nov.

Planta a specie differt frondibus tenuioribus, usque ad 300 μ diam., intricatis, hinc illinc inter se per tenacula rhizoidea adhaerentibus. Specimen typicum: *Tseng 2682* (in herbario auctoris) prope Clear Water Bay, Port Shelter, 22 Mar., 1940.

This new form of *P. ferulacea* has a densely intricate frond with the filaments here and there united to one another by rhizoidal filaments acting as tenacula. These rhizoids, about 45 μ in diameter, are either unicellular or septate, and all are separate from the mother pericentral cells by cross walls (Pl. III, Fig. 4). The branching is irregularly alternate, appearing subdichotomous at places, with some apices more or less forked like those of the members of Ceramium (Pl. III, Fig. 5). The filaments are rigid and brittle, easily broken, often with stunted tips, frequently proliferating new, regenerating filaments. They are 200–300 μ in diameter, branches of all orders being of approximately the same thickness, except near the tips, where they may taper to 90 μ in diameter. They are tetrasiphonous (Pl. III, Fig. 7), ecorticate, and distinctly articulate throughout. The pericentral cells are subquadrate in surface view, one half to one diameter long or slightly longer. The segments are very short, always shorter than broad, frequently only about one half to one third the diameter in length (Pl. III, Fig. 4). The trichoblasts are well developed, and are arranged on a one-quarter divergence (Pl. III, Fig. 4). The branches are lateral in origin, replacing the trichoblasts. The tetrasporangia are 60–80 μ in diameter when mature; they are spirally arranged in densely forking terminal branchlets, more or less distorted and swollen, the fertile segments about 150 μ in diameter (Pl. III, Fig. 6).

Habitat.—Stanley Beach, Hong Kong Island, where they are washed ashore; in May (*McClure A 81*) and Clear Water Bay, Port Shelter, in May (*Tseng 2682*, TYPE of f. *implicata*).

Distribution. West Indies (the probable type region), Mexico, Guadeloupe Island, Sandwich Islands, Australia, South Japan, and, India.

Since *Polysiphonia ferulacea* is a very widely distributed plant of the tropical and subtropical waters, there has naturally been some

controversy, fortunately very little, as to the interpretation and delimitation of it. With regard to the origin of the branches, Collins and Hervey, *loc. cit.*, mention that "Leaves are abundant, branches being produced from their axils." Having examined numerous West Indian specimens of the species, the writer has come to agree with the views of Howe, Borgesen, and Taylor that the branches are independent of the trichoblasts and are lateral in origin. In the matter of length of the segments, Yendo, *loc. cit.*, made the following remark: "The length of the articuli was also greatly variable, sometimes as long as 6–8 times the diameter as Harvey noted, but frequently as short as only 1.5 times." It must be stated that Harvey, *loc. cit.*, mentioned "articulations in all parts of the frond much shorter than their diameter" rather than "6–8 times the diameter," as Yendo wrote. It seems to the writer that Yendo had a very broad view of this species, apparently including a heterogenous group, since the shortness of the segments has been generally accepted by phycologists working more intensively on tropical forms as one of its more constant and conspicuous characteristics.

Collins and Hervey, *loc. cit.*, remarked that they found plants agreeing closely with *P. fracta* Harv., which seemed to them "to be an old and battered form of *P. ferulacea*." They added, further: "Authentic specimens of the latter, in the Farlow Herbarium, confirm this view." It seems, therefore, that a rechecking of the type specimens of *P. fracta* is very necessary and, if it proves to be the same as *P. ferulacea*, as Collins and Hervey suspected, the specific epithet *fracta* of Harvey (1853) has to be used instead of the now current "*ferulacea*" of Suhr, ex J. Agardh (1863).

The forma *implicata* differs from the typical form of the species in its intricate frond, with abundant tenacula produced everywhere, attaching the filaments to the substratum as well as to one another, making it almost impossible to separate the branches from one another without breaking some of them. The Hong Kong form is also more slender and shorter than the typical one, and has smaller filaments. Its apices are also generally forcipate, like those of the ceramiums. In its external characteristics, therefore, it is very different from the typical erect, tufted, rather regularly and abundantly subdichotomously pinnate form of the West Indian region. In other important characteristics, for instance, the cells, the segments, the tetrasporangial stichidia, there is no fundamental difference that the

writer can find to distinguish it from the typical form. It is therefore regarded merely as an environmental form of the West Indian plant. Since the typical form has been reported from Japan on the east of this region and from India on the west, it seems less probable that the Hong Kong plant is a geographic variety. As noted above, McClure's No. 81 also belongs to the present form. This specimen, by the way, bears the identification of Professor Setchell as "*Polysiphonia sp.* cf. *P. ferulacea*, probably undescribed."

6. *Polysiphonia Harlandii* Harv.

(Plate IV)

Charact. New Alg., 1860, p. 330; J. Agardh, Species algarum, II (3), 1863, p. 1063; De Toni, Sylloge algarum, IV (3), 1903, p. 913; Yamada, Notes on Japanese Algae, V, 1933, p. 283, pl. 13, fig. 3.

The present species was described originally from Hong Kong by Harvey, *loc. cit.*, on the basis of the material collected by Charles Wright in the United States North Pacific Expedition under Captain John Rodgers. It was listed under "Species Inquirendae" by J. Agardh, *loc. cit.*, who, as well as De Toni, *loc. cit.*, merely transferred Harvey's description to his work. The species was not again heard of until quite recently, when Yamada, *loc. cit.*, reported it from Formosa, claiming that he "was fortunate enough to have been able to compare these specimens with the type specimens of Harvey at Dublin and came to the conclusion that the Formosan specimens were to be referred to the present species." He published a photograph of two specimens, but, unfortunately for fellow phycologists, did not describe the plants at all. Plants that appear to be of this species, to judge from the photograph published by Yamada and from Harvey's original description, are very common from December to May in exposed places on the southeastern part of Hong Kong Island. In the past few years the writer had paid special attention to the collection of specimens showing the various stages of development and the fruiting materials. In view of the fact that the species is still so imperfectly known a rather detailed description of this plant will be given in the following pages which, the writer hopes, may help to define it more clearly.

Plants of this species attain a height of 6.5 cm., and are dark reddish to brownish purple, rather rigid below and very soft above,

tufted from a basal disclike holdfast, with a dozen or more erect filaments in the same group. The holdfast is a large aggregation of rhizoids that grow out from the small cortical cells of the basal parts. The main axis is percurrent and laterally branched in all directions. This and its main branches are more or less naked in the lower portion, and are only sparsely beset with small branchlets, but very densely clothed with branchlets in all directions above. The branchlets are densely and repeatedly forked, with tufts of well-developed trichoblasts at the tips; they are lateral, originating without reference to these "leaves."

The filaments are tetrasiphonous, with rather light cortication in the main axis and the principal branches, where the articulations are not clear (Pl. IV, Figs. 3–4). In the younger parts and the branchlets they are ecorticate and distinctly articulate. There the segments are short, generally one half to one diameter long. The main axis reaches a diameter of 1.2 mm. The dichotomously decompound branchlets are 160–200 μ in diameter below, decreasing gradually to about 30–45 μ in diameter at the apices. The trichoblasts are repeatedly dichotomous, about 10–12 μ in diameter at the base and 4–6 μ near the tips.

The tetrasporangia are found near the tips and, in mature fronds, extend from the apices downward to two, rarely three, orders of the last few dichotomies (Pl. IV, Fig. 4). They occur in rather long spiral series; as many as twelve have been counted in a single consecutive series, with the oldest ones lowermost and the youngest uppermost. The older, mature, ones are, as is to be expected, more prominent, but the younger ones are generally rather inconspicuous. This might have accounted for the following description of the sporangia by Harvey, "sub apice ramulorum solitariis," since the small, inconspicuous sporangia, especially in dried specimens, are rather difficult to detect, whereas the one or two large, mature, conspicuous sporangia in the lowermost part of the series could easily attract one's attention. The fertile branchlets are greatly or slightly swollen and distorted. Mature sporangia attain a diameter of 75 μ.

The pericarps are short-pedicellate, with a stalk about 60 μ long on the longer, dorsal, side and less than 10 μ on the shorter, ventral, one. They are abundantly found on the dichotomously decompound ultimate branchlets. They are obliquely and fastigiately placed, long-ovate when young, becoming broadly subspherical when ma-

ture, generally to about 0.1 mm. (sometimes 0.15 mm.) broad, and 0.36 mm. (sometimes 0.40 mm.) long, each without a protracted neck and with a very broad ventrally situated terminal ostiole (Pl. IV, Fig. 2). The spermatangial clusters are developed on the trichoblasts, each replacing an arm of the first dichotomy (Pl. IV, Fig. 1). They are subcylindrical, about 15 μ in diameter and 165 μ long, each terminating on a sterile cell.

Habitat. — Abundant on surf-beaten rocks in the lower littoral region, Hong Kong Island; Shek-O, in March (*Tseng 655*, *2660*) and December (*Tseng 2601* and *Taam A 12*); and Stanley Beach, in March (*Tseng 576*).

Distribution. — Hong Kong (type locality) and Formosa.

As mentioned above, in identifying these specimens with *P. Harlandii* Harv. the writer has not been able to compare them with authentic specimens. No illustrations have ever been published to show the important detailed microscopic characteristics of the species. Nevertheless, in spite of these difficulties, he has no hesitation in referring them as indicated above, because these specimens represent the most common species of Polysiphonia on the island and are the only ones that match perfectly with the original description of the Harveyan species.

The description given above refers to the typical form of *P. Harlandii* Harv., according to the interpretation of the writer, which is based on topotype material. This he proposes to name forma **typica,** nom. nov., based necessarily on Harvey's type specimen. In the course of his study of other algae the writer found several small corticated epiphytic Oligosiphonia with full loads of tetrasporangia in some and cystocarps in others. A study of them shows that they are not fundamentally different from *P. Harlandii,* so far the only corticated species discovered in this region, in spite of the fact that these plants are only one tenth to one twentieth as large as the normal mature ones of the typical form. This the writer proposes to call forma **minutissima,** f. nov.

Planta a forma typica differt frondibus et partibus omnibus multo tenuioribus; frondibus ca. 4 mm. altis, filamentis usque ad 0.5 mm. diam., cystocarpiis 280 μ latis, 300 μ longis; ramulis ultimis minus ramosis. Specimen typicum: *Tseng 2698a*, in *Laurencia undulata*, prope Cape d'Aguilar, Hong Kong Island, 24 Mar., 1940.

Plants of this new form are epiphytic on *Laurencia undulata* and are about 2 4 mm. high, yet fully mature asexually and sexually. They attach to the host by means of basally issued rhizoids. The main filaments are generally 250-350 μ in diameter, but in some as much as 0.5 mm. in diameter. Like that in the typical form, the cortication is light, and the articulated portions have segments much shorter than broad. The tetrasporangia are about 60 μ in diameter, and are disposed as in the species. The fertile branchlets are also swollen and distorted, but are much less branched, with only few dichotomies. The pericarps are ovate to subspherical, short-pedicellate, to 280 μ broad and 300 μ long.

SUMMARY

Of the six species of Polysiphonia two are described here for the first time. These are: *P. coacta* Tseng, sp. nov., probably closely related to the Cape species, *P. incompta* Harv.; and *P. gracilis* Tseng, sp. nov., most closely related to the Indian species, *P. platycarpa* Børg. Of the remaining species, *P. subtilissima* Mont., *P. Savatieri* Hariot, and *P. ferulacea* Suhr ex J. Agardh are recorded here for the first time for the Hong Kong region as well as for the entire China coast. A new form, f. *implicata* Tseng, f. nov., is now first described for the West Indian species, *P. ferulacea*. The last member, *P. Harlandii* Harv., technically a "native" of this region since it was based on Hong Kong material, is described in some detail, based on topotype materials. Besides the typical form (f. *typica* Tseng, nom. nov.) a new form, f. *minutissima* Tseng, f. nov., was found as a small epiphyte on other algae. All these species are four-siphoned, belong to the section Oligosiphonia, and, with the exception of *P. Harlandii*, are all ecorticate.

The writer wishes to thank Professor Wm. Randolph Taylor, of the University of Michigan, for his advice during this study.

University of Michigan

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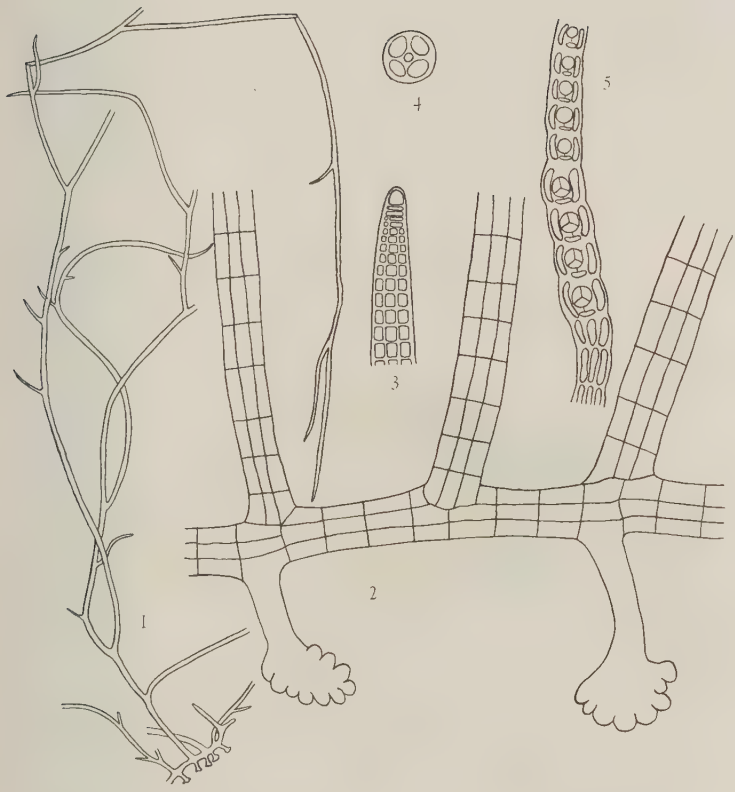


Polysiphonia subtilissima Mont.

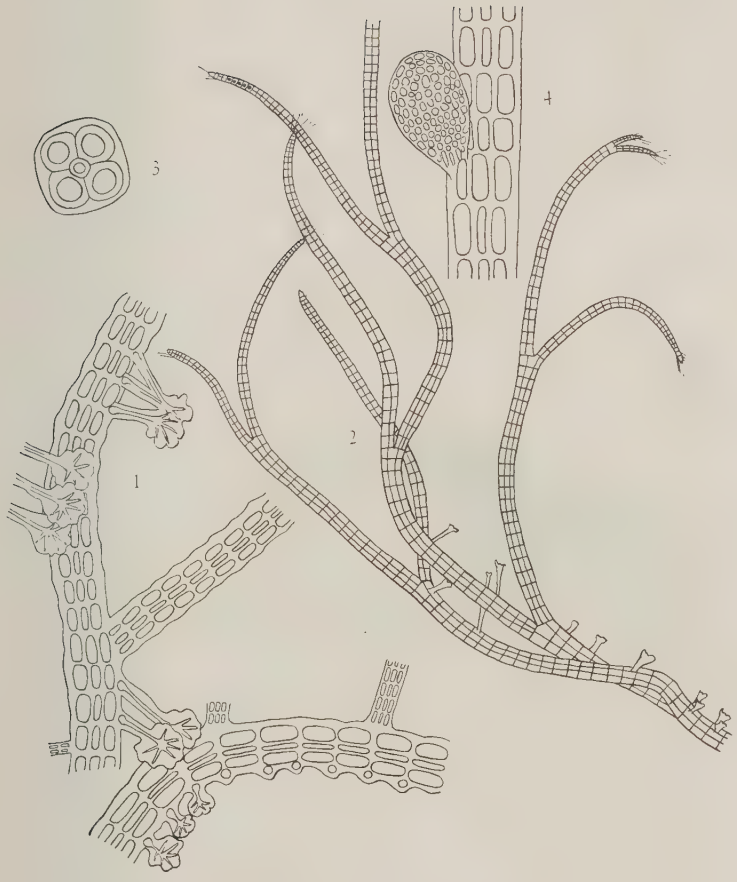
Fig. 1. Habit sketch. × 11

Fig. 2. Part of basal stoloniferous filament, showing origin of rhizoids. × 100

Fig. 3. Tip of filament, showing apical cell. × 206

Fig. 4. Transverse section of filament. × 206

Fig. 5. Part of tetrasporiferous filament. × 100



Polysiphonia coacta Tseng, sp. nov.

Fig. 1. Basal filaments, showing rhizoids. × 46
Fig. 2. Habit sketch of tetrasporiangiate plant. × 19
Fig. 3. Transverse section of filament. × 100
Fig. 4. Part of filament, with young cystocarp. × 100

EXPLANATION OF PLATE III

FIG. 1. *P. Savatieri* Hariot. Tetrasporangiate branchlet. × 76

P. gracilis Tseng, sp. nov.

FIG. 2. Part of tetrasporic plant, showing branching and elongated tetrasporangial series. × 17

FIG. 3. Part of branchlet, showing rhizoid. × 76

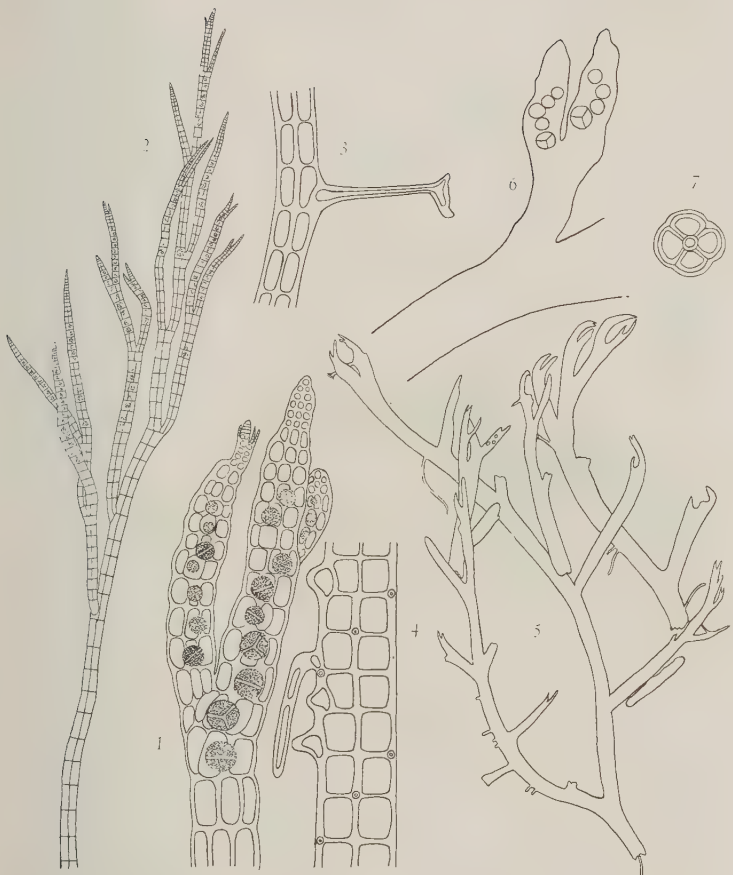
P. ferulacea Suhr ex J. Ag., f. *implicata*, f. nov.

FIG. 4. Part of filament, showing pericentral cells, trichoblast rudiments, and rhizoids. × 76

FIG. 5. Habit sketch of part of plant, with broken filaments of others of same plant, and intersegmental rhizoidal tenacula. × 10

FIG. 6. Tetrasporangiate branchlet. × 40

FIG. 7. Transverse section of filament. × 40



Species of Polysiphonia

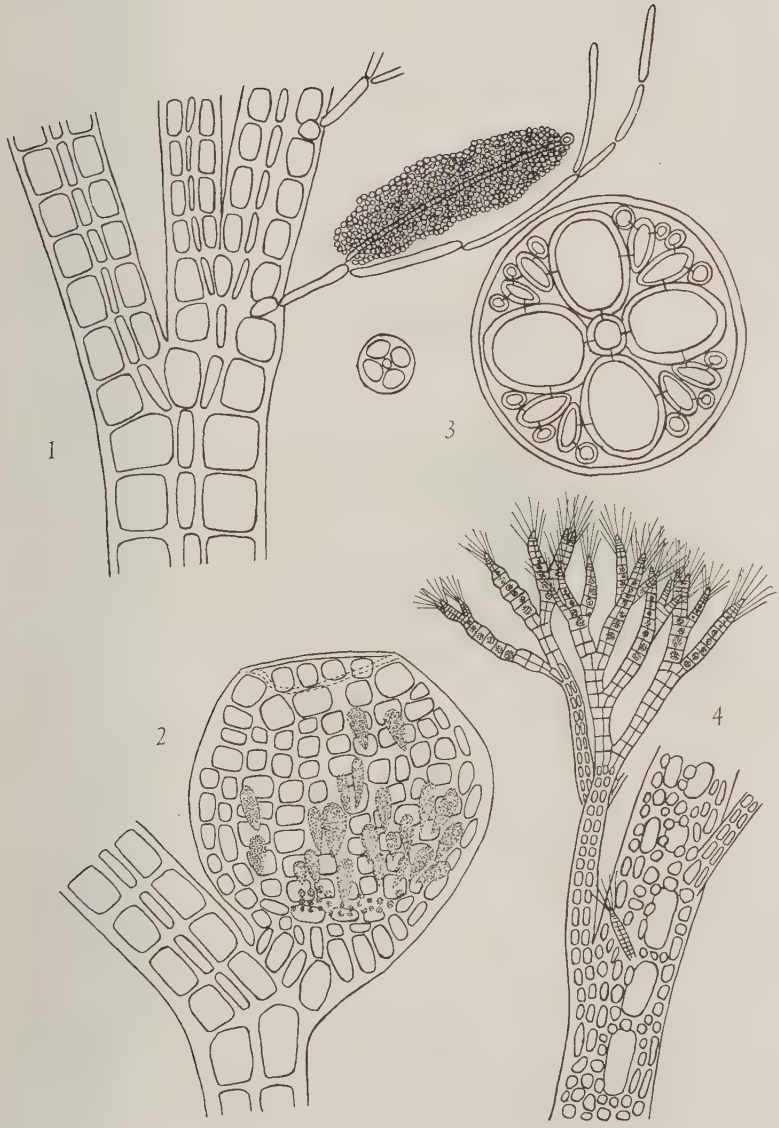
EXPLANATION OF PLATE IV

FIG. 1. Part of branch, showing spermatangial cluster. × 212

FIG. 2. Part of branch bearing a cystocarp. × 106

FIG. 3. Transverse section of young branchlet (left) and another of a principal branch. × 56

FIG. 4. Part of branch with tetrasporangiate branchlet, showing cortication. × 30



Polysiphonia Harlandii Harv. f. *typica* Tseng, nom. nov.

FORESTRY

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. XV*

DOW V. BAXTER

THE genera Poria, Trametes, and Polystictus (which is often resupinate in the tropics as well as elsewhere) include several species of fungi that attack woods used for military purposes. The losses they cause, both directly and indirectly, may be shown by numerous communications from war fronts all over the world. That decay in crating and shipping containers is serious is shown by the following note received from Africa: "Pine boxes, opened up the other day [censored words] were lined with *Poria incrassata* (sp.?) a quarter inch thick. They nearly fell apart with a few blows of the hammer."

In a communication from "down under" the prevalence of decay in wood used locally by the army is indicated by this excerpt: "I am on an island somewhere in the southwestern Pacific . . .; have been cutting some of the so-called Australian pine . . ., which only grows along the coast, seldom over more than 100 yards away from the ocean . . .; butt rot seems to be present in definite groves. Some trees will be rotten clear through, while others just three or four feet up in the trunk."

An employee of the Board of Economic Warfare in Ecuador writes: "There is a factor here that affects all calculations, and it is extremely hard to figure. Balsa is a delicate wood. If the logs are

* Throughout the work on these monographs I have been indebted to many individuals and institutions for suggestions, help, and privileges. My appreciation is expressed particularly to the men who have accompanied me on my ten expeditions to Alaska, the Yukon Territory, and the Northwest Territories. They aided in the collection and care of specimens, sometimes under rather difficult circumstances. I am under obligation to Professors T. G. Halle and Gunnar Samuelson, of Naturhistoriska Riksmuséet in Stockholm, with whom I have had the pleasure of association. Thanks are due to several American institutions and scholars also: to the authorities at the New York Botanical Garden; to Dr. W. H. Long, Albuquerque, New Mexico; to the staff of the Division of Pathological and Mycological Collections of the United States Department of Agriculture; and to Professor H. H. Bartlett and Reed W. Varner, of the University of Michigan.

left long before milling they are greatly damaged by worms and checks. Decay starts about as soon as the tree is felled. The result is that many logs are absolutely worthless by the time they reach the mill. This degrade is shown by the fact that since the beginning of the year the most efficiently operating mill in the area averaged 68 board feet out of logs averaging 144 board feet per log."

Since long periods of transit are inevitable during a war and since the methods of handling war materials are becoming more complex, there is urgent need of information on the rate of growth of wood-destroying fungi and on the temperatures at which they thrive. It is my plan to discuss these fungi in three groups: (*a*) white, (*b*) brown, and (*c*) those other than white and brown. The present paper, in which the first group is treated, is based largely upon studies of the rate of growth in culture and other features. It is intended to serve as a guide to the principal white resupinate polypores in North America.

THE RESUPINATE POLYPORES IN CULTURE

Identification of the causal organisms of decay is greatly facilitated by a study of variations under field conditions. About one hundred and fifty isolates and species collected from widely separated areas of the continent form the basis for this work. The practicability of a key that separates the different species and isolates is dependent, however, upon an understanding of variable reactions of the fungi themselves (even under controlled environments), method and type of culture, and an awareness that physiological characteristics do not always conform to morphological differences. Two plants that are distinct morphologically may exhibit like features in culture.

The usual initial classification of a fungus, based upon mycelial features, is made by comparing the unknown culture with a stock collection from named plants. Obviously the larger and more representative the reference collection of species and races is, the greater are the possibilities of arriving at the correct identification of a fungus.

An adequate number of the resupinate polypores from such a vast area as the North American continent has yet to be brought together. There is great danger, in work of this nature, of not having an unidentified species, or races of it, represented among the named plants. Furthermore, if pore formation does not occur in

an isolate from wood, it may not be a polypore at all, but some other fungus, such as a member of the Thelephoraceae. Five cases of flask cultures are included in the collection of the School of Forestry and Conservation of the University of Michigan (see Pl. VI). This stock collection of the various fungi on red-gum test pieces, which is duplicated on white pine blocks, is most useful in making comparisons much as one does between an unknown and an authentic herbarium specimen when descriptions are difficult to interpret. In fungus cultures many of the possible elements are nearly alike, or they are often variable, or some elements occur in so many different species that they cannot be used as a basis for separation. After a determination of a fungus in a key, a final comparison with a reference collection is highly desirable and often necessary.

Since the concepts of Friesian species are based largely upon morphological features it seems reasonable to consider such characters of fundamental importance in the identification of a polypore. If possible, the determination of a species should be based upon structures of the fruiting body itself. Cultures, on the other hand, are most helpful in determining races. Furthermore, they are often essential in identification work if fruiting bodies are absent or immature. Reactions in culture may be used to separate plants that are closely allied morphologically if the structural features described for the species have only minor distinguishing characteristics, or if they are known to exhibit variations in different environments.

There are certain objections to the selection of almost any element that may be adopted to form the structure of a key to the fungi in culture. Some of these relate to the time, the equipment, and perhaps the difficulty involved in making the tests, whereas others are concerned with the variations shown by the fungi themselves. In some species color, for example, varies with the intensity of the light, and it often changes with the aging of a culture. Temperature may also affect color, as can be observed when tests are made at constant temperatures. Often the color in young cultures, in *Poria ferrea*, for example, is mostly white and not at all like that of the brown fruiting body of the plant in nature.

In general, microscopic structures are less variable than such features as color, texture, and rate and form of growth, and so may often be used to advantage. The presence or the absence of clamp connections, chlamydospores, conidia or oidia, staghorn and other

types of branching of the mycelium, the diameter of the hyphae, setal hyphae, and setae are important elements in making up a key. The existence or the lack of clamp connections, however, was of little use in constructing the key presented here since they occur so generally in the white group of resupinate species reported. As a rule, clamp connections do not occur at all in the brown group, which is composed of a number of species, such as *Fuscoporia* (*Poria*) *rufitincta*, *Fomitiporia dryophylla*, *F. Earleae*, *Fomes nigrolimitatus*, *Poria laevigata*, *P. prunicola*, *P. inermis*, and *P. tsugina*. By means of the presence or the absence of clamp connections one might easily separate a group of fungi in which these plants are included from a category containing white species. However, one never experiences any difficulty in distinguishing between isolates of this brown group and the white or whitish species. The two groups can be separated by other means more conveniently than by a microscopic examination of the mycelium, for color alone can usually differentiate them.

Difficulty is encountered when it becomes necessary to distinguish between the fungi within the brown group or within a large group of white plants without resorting to physiological characteristics. Microscopic structures such as the spines that occur on the mycelium of *Poria spiculosa* Campbell and Davidson (4) are important and definite.

The use of certain other microscopic features may be limited by the fact that their incidence varies somewhat with environmental factors, such as the age of the culture and thickness of the medium. It is well known that moisture may influence not only spore production, but also the type of spore formed. In several species of the Polyporaceae, for example, Bose (2) reports that, after the rainy season in India and at intervals between showers, basidia in fruiting bodies are transformed into hyphal elongations with terminal spores. Conversely, if showers occur in the middle of the dry season, the hymenial elongations soon become reconverted into basidia. He states that it is possible to demonstrate such conversion of spore formation in cultures.

Among the physiological reactions of a fungus that may enable the investigator to make certain distinctions between plants is the one determined by the use of the Bavendamm oxidase test (1). This test is made by culturing the fungus on malt agar containing 0.5 per cent tannic or gallic acid. In general, it is possible to sepa-

rate the fungi that cause brown rot from those that bring about a white decay. Those that induce brown rot react negatively, and so do not darken the medium under the fungus mat. If fungi that cause a white rot are cultured, the agar beneath and surrounding the mat becomes discolored.

Two of the chief disadvantages of using the reaction to the oxidase test as an element of a key are the time and the effort required for the task. One can ordinarily determine whether a white or a brown rot is produced by an examination of the wood from which the isolation is made. If, on the other hand, the isolation is made from a fruiting body, means of identification more direct than cultures are usually available.

Time, effort, equipment, and variation in growth of the fungus are also factors important in making identifications on the basis of rate of growth at constant temperature. Much more time and effort are needed to test the growth of mycelium on coniferous and hardwood blocks. Such tests, however, have a multiple use. Records giving data on rate of growth, mycelial development on wood, and the effect of the fungus on wood not only are useful for purposes of identification in a key, but have other values that are often significant in pathology.

If one does not have wood-block cultures for comparison, the microscopic and other features listed in the key with the isolates are for the most part characteristic of the fungus in two-week-old petri-dish tests, so that comparisons may be made on this basis. Examination of the plates accompanying the text will be helpful if texture and form of growth are elements mentioned.

In cultures of *Fomes annosus* the practically constant occurrence of conidiophores with spiked heads, which can be seen under the microscope, is distinctive for the species and is used as the first element to separate this fungus from the others in the white group. Their presence can be determined without experiencing the difficulty of keeping the fungi at different temperatures, and these structures are constant in the fungus. It is necessary, however, to resort to the use of both physiological and other features as elements of a long key.

The descriptions mentioned in the key presented in this paper are based in general on not fewer than eighteen tests, and for those experiments in which wide variations occurred, upon numerous other

tests. It is characteristic of certain species to be relatively constant in their reactions and of others to vary greatly. In most species greatest variation occurs at temperatures critical for their growth. Those which are not constant in their growth reactions are listed in more than one division of the key.

Allowances are necessary, again particularly at critical temperatures, for growth rates for those isolates which have been cultured constantly on malt agar over a number of years. Although various species are affected differently, this is likely to be particularly true if in the meantime the fungus has not been grown on wood or on a medium other than malt-extract agar. Several cultures of the resupinate polypores when not made on wood and reisolated have shown at least some indication of growing more slowly at critical temperatures within two-week-old tests than they did twelve years ago. For this reason, too, certain species are included in more than one section of the key.

Only cultures that are made from actively growing mycelium should be compared with those mentioned in this paper. Cultures obtained from stock that has been stored at cold temperatures for long periods or cultures prepared directly from dishes in which the agar has become desiccated may be slow in starting their growth. The petri-dish records reported in this paper are based on inoculum obtained from two-week-old transfers.

Some species cannot be traced beyond a general grouping in a key based solely on features exhibited in culture. For example, *Poria ancirina*, *P. mollusca*, *P. xantha crassa*, and *Trametes serialis* are distinct species, yet some isolates of these fungi show characteristics when cultured which cause them to be brought together in sections of the key.

Submerged mycelium is not always visible unless the petri dishes are held up to the light. Consequently the total amount of growth indicated in the key may not be shown clearly by the plates accompanying this paper. Furthermore, when wide variation has been the pattern of growth, photographs that indicate the amount of mycelium most usually obtained in the tests are presented.

Young cultures of several of the brown resupinates and those of a number of other colors are white at first. Likewise certain porias that have truly white fruiting bodies become discolored in one-year-old flask cultures. Some porias, for example, *Poria unita pulchella*,

are white or yellow, depending upon light conditions. The temperature ovens used in these studies are dark. However, the principal resupinates of the American continent that fall into the categories mentioned are included in the key.

KEY TO THE PRINCIPAL WHITE RESUPINATE POLYPORES IN CULTURE

The white or whitish mycelium shown in both petri-dish tests and one-year-old wood-block cultures characterizes the resupinate polypores listed in this key. Certain species having fruiting bodies that are brown or of some other color are included in this group, however, since they either exhibit a whitish mycelium for a number of weeks or show white as well as colored mycelium in cultures. *Poria ferrea*, *P. rufa*, and *P. nigra* are examples. A key to the colored resupinate polypores will be presented in Number XVI of this series.

All growth measurements are averages of the two longest radii emanating from the inoculum, which was not measured.

The color terms enclosed in quotation marks are those of R. Ridgway, *Color Standards and Color Nomenclature* (1912).

I. Conidiophores, simple or branched (and suggestive of those of an Aspergillus), produced on broad hyphae; the swollen apex of the structure left with a number of pointed sterigmata after the spores have fallen
Fomes annosus on coniferous timber

I. Conidiophores not present or, if secondary spores are formed, not produced on the swollen apex of a structure with a number of pointed sterigmata II

II. Superficial mycelium with staghorn branches
F. lobatus isolate reported by Campbell (3) (mycelium forming a dense compacted yellow to drab central zone, containing cuticular cells)
F. applanatus isolate reported by Campbell (3) (cannot always be separated from *F. lobatus*, which usually has a yellow to drab central zone. Both have cuticular cells)
F. fraxineus isolate reported by Campbell (3) (production pores and chlamydospores distinguish this fungus from *F. applanatus* and *F. lobatus*)

II. Superficial mycelium without staghorn branches 1

1. Mycelial growth filling petri dishes in two-week-old malt-agar cultures at 35° C. 2
1. Mycelial growth not filling petri dishes in two-week-old malt-agar cultures at 35° C. 5

2. Mycelium yellow, i.e. "Naples yellow," at least on inoculum, as well as white

A. Mycelium in one-year-old red-gum block cultures "avellaneous" as well as white; no pores formed; mycelium not much branched and not particularly narrow

T. rigida on *Q. Shumardii*, Florida (Pl. I)

T. subserpens sensu Murr. on *Nyssa biflora*, Florida. (This isolate may prove to be *T. rigida* when *T. subserpens* is better known.)

A. Mycelium in one-year-old red-gum block cultures white or yellow,[1] but not "avellaneous"; pore formation common; mycelium usually much branched and narrow

P. unita on *Quercus sp.*, Michigan (Pl. I)

P. unita pulchella on *Populus balsamifera*, Great Slave Lake, Northwest Territories

2. Mycelium white or whitish, but not at all "Naples yellow" 3

3. Cultures at 35° C. appearing water-soaked or arachnoid, i.e. not leathery or like chamois skin, but agar visible from beneath mycelium; culture therefore not distinctly snow white, mycelium never so luxuriant that it grows out of the petri dish

A. Mycelium in one-year-old red-gum block cultures growing so luxuriantly that the shape of the test pieces is masked from view, i.e. blocks completely enveloped and edges not visible

F. pinicola on *Pinus ponderosa*, Oregon

A. Mycelium in one-year-old red-gum block cultures not growing so luxuriantly that the shape of the test pieces is masked from view, i.e. edges of blocks visible ..... B

B. Mycelium in one-year-old red-gum block cultures nodular, often forming irpiciform pore surfaces

P. albobrunnea on *Pinus caribaea*, Georgia (Pl. II)

B. Mycelium in one-year-old red-gum block cultures not nodular C

C. Mycelium in one-year-old red-gum block cultures distinctly rhizomorphic, mycelium often becoming "avellaneous" or light brown in old cultures ..... E

C. Mycelium in one-year-old red-gum block cultures not distinctly rhizomorphic ..... D

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[1] The color of the mycelium in *Poria unita* and *P. unita pulchella* is influenced by light conditions.

D. Mycelium in one-year-old red-gum block cultures forming a white mat that covers the wood and remains white in old cultures

P. albipellucida on *Tsuga heterophylla*, Washington (Pl. I)[2]

D. Mycelium in one-year-old red-gum block cultures not forming a white mat that completely covers the wood and remains white in old cultures; but often powdery and all or most of the wood visible from beneath the fungous growth

P. tacamahacae on *Populus balsamifera*, Waterways, Alberta (Pl. I)

E. Mycelium in one-year-old red-gum block cultures pinkish brown, rhizomorphs often salmon-colored

P. semitincta on *Q. marilandica*, North Carolina

E. Mycelium in one-year-old red-gum block cultures mostly snow white, not pinkish brown, rhizomorphs whitish or "avellaneous"

P. subfusco-flavida on *Pseudotsuga taxifolia*, locality unknown (Pl. II)

3. Cultures not appearing water-soaked or arachnoid at 35° C., i.e. agar not visible from beneath the snow-white mycelium, or, if water-soaked in spots, the mycelium growing at such a rapid rate that it extends out between the lid and the dish 4

4. Mycelium appearing distinctly flaky, i.e. not exhibiting a uniform growth in cultures at 30° C., mycelium developing so luxuriantly that it grows out of the petri dishes

Pol. anceps on *Picea glauca*, Fort Wrigley, Northwest Territories (Pl. II)

4. Mycelium not distinctly flaky, but exhibiting a generally uniform type of growth over the agar surface at 30° C. and in some species developing so luxuriantly that it extends out from beneath the lid of the petri dish; often like chamois skin 22

5. Mycelium not filling petri dish at 35° C., but growing more than 10 mm.[3] in two-week-old cultures 6

5. Mycelium showing no growth or growing less than 10 mm. at 35° C. .. 9

6. Culture appearing water-soaked or mycelium appressed at 35° C.

A. Mycelium in one-year-old red-gum block cultures pink or pinkish or pinkish brown C

A. Mycelium in one-year-old red-gum block cultures not pink or pinkish ..... B

B. Mycelium completely enveloping red-gum blocks in one-year-old cultures so that their shape is entirely masked, i.e. no sharp corners or edges visible

F. pinicola on *Populus balsamifera*, Michigan

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[2] Spores are not allantoid, but globose or subglobose, (3) 3.5 — 4.5 × 4 — 4.5 (5) μ.

[3] Fungi exhibiting a growth between 5 and 10 mm. are included in both divisions throughout the key.

B. Mycelium not growing so luxuriantly that the wood blocks become masked from view; corners and edges remain distinct

P. albipellucida on *Tsuga heterophylla*, Washington (no pore formation; irregular growth mat in petri dishes at 30° C.) (Pl. I)

P. tacamahacae on *Populus balsamifera*, Waterways, Alberta (no pore formation; irregular growth mat in petri dishes) (Pl. I)

P. xantha crassa U. 28 on *Salix interior*, Providence, Northwest Territories (no pore formation)

P. xantha on *Pinus palustris*, Florida (no pore formation; smooth growth mat in petri dishes)

C. Mycelium in one-year-old red-gum block cultures pink or pinkish, nodular fructifications exhibited, mycelium not at all rhizomorphic

F. subroseus on *Larix laricina*, Michigan

C. Mycelium in one-year-old red-gum block cultures pinkish brown, mycelium rhizomorphic

P. semitincta on *Quercus marilandica*, North Carolina

6. Cultures not appearing water-soaked at 35° C. 7

7. Mycelial growth thin, arachnoid at 25° C. and somewhat water-soaked at this temperature, even though not appearing water-soaked at 35° C.

P. xantha crassa, on greenhouse bench timber, England 381

7. Mycelial growth thick, like chamois skin or cottony at 25° C. 8

8. Mycelial growth "avellaneous" or pinkish at 25° C., at least on inoculum, as well as white in two-week-old cultures (in *Poria nigra* 71099 as "avellaneous" as white, whereas in *F. fraxinophilus* more of the mycelium white than "avellaneous")

A. Mycelium in one-year-old red-gum block cultures dark brown, i.e. "bister," "Verona brown," or "Mars brown," as well as whitish

P. nigra ex Division of Forest Pathology, Washington, 71099 on *Quercus velutina*, Illinois (some hyphae with brown walls)

Unknown Poria on *Taxodium distichum*, railroad ties, Georgia. (Six-month-old red-gum block cultures are identical in color with *Poria nigra* 71099. Both fungi grow luxuriantly, but growth of *P. nigra* does not completely mask general shape of test pieces from view. Hyphae hyaline)

A. Mycelium in one-year-old red-gum block cultures white to "avellaneous," but not dark brown, i.e. "bister"

F. fraxinophilus on *Fraxinus americana*, Michigan

8. Mycelial growth not "avellaneous" but snow white at 25° C. in two-week-old cultures

A. Mycelium in one-year-old red-gum block cultures somewhat cottony, at least not smooth as in a glassy surface

T. Morganii on *Quercus sp.*, Virginia

A. Mycelium in one-year-old red-gum block cultures not at all cottony, but smooth as in a painted surface

T. serpens on *Carpinus sp.*, sensu Lloyd Cat. No. 35980, Florida (not *T. serpens* Fr. sensu Romell and contemporary Swedish scholars. This Florida isolate is most nearly related to *T. subserpens* Murr. or *T. rigida* Fr.)

9. Mycelium essentially filling petri dishes at 30° C. in two-week-old cultures 10
9. Mycelium not filling petri dishes at 30° C. in two-week-old cultures ... 17

10. Cultures whitish yellow [4] at 30° C., not snow white, i.e. yellow or yellow cream as well as whitish; mycelium mostly thin on agar surface or forming coarse strands 11
10. Cultures white at 30° C. or "avellaneous" or slightly pinkish or water-soaked, i.e. agar color showing from beneath mycelium, but culture not cream or yellowish, mycelium thin or thick 12

11. Mycelium appearing in coarse strands (i.e. not fine arachnoid threads) which radiate out from inoculum or form a distinct fanlike or radiate type of growth

P. incrassata ex U. S. Forest Products Laboratory, Madison (Pl. II)

11. Mycelium forming uniform growth over medium, not in coarse strands and not exhibiting a radiate type of growth

P. xantha crassa ex Canadian Forest Products Laboratory, 349–3–Q, Canada

P. xantha crassa, "A," Mt. McKinley, Alaska

P. xantha crassa on *Salix interior*, U. 28. Providence, Northwest Territories

P. xantha on *Pinus palustris*, Florida

P. xantha crassa U. 34 on *Picea glauca*, Fort Wrigley, Northwest Territories

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[4] Throughout the key, where the separation of species is based upon relative features, the plants are placed in both sections. Since it may be difficult to determine, for example, whether a culture is whitish or "avellaneous," it becomes necessary to list the species in more than one group.

P. xantha crassa, on greenhouse bench timber, England 381

12. Culture appearing water-soaked, i.e. mycelium not completely masking agar from view at 30° C. 13
12. Culture not appearing water-soaked, i.e. mycelium masking agar from view at 30 ° C. 14

13. Mycelium more arachnoid (i.e. in fine threadlike strands that extend outward) than granular or powdery; culture may or may not always exhibit aërial mycelium in two-week-old cultures (often trace of cream color in various isolates of *Poria xantha*, the variety of *P. xantha crassa*, and often a trace of pink or "avellaneous" in area about inoculum in *P. semitincta*)

A. Mycelium in one-year-old cultures "vinaceous-fawn" as well as white; blocks collapsed from decay so that they no longer are square in cross section

P. semitincta on *Quercus marilandica*, North Carolina

A. Mycelium in one-year-old cultures not "vinaceous-fawn" as well as white, blocks collapsed or not collapsed ..... B

B. Mycelium forming a thick mat over the surface of red-gum test pieces in one-year-old cultures, so that the edges of the blocks are rounded, i.e. not sharp, and often the shape of the test piece completely concealed C

B. Mycelium not forming a thick mat over the surface of red-gum test pieces in one-year-old cultures, so that the edges of the blocks are hidden from view ..... D

C. Mycelium in one-year-old red-gum block cultures forming large globular masses of fungous tissue; mycelium appearing as fleecelike coverings of the test pieces which can be separated from the wood blocks by shaking the flasks

F. pinicola on *Populus balsamifera*, Michigan (cultures more "avellaneous" than pink)

C. Mycelium in one-year-old red-gum block cultures not forming large globular masses of fungous tissue, although sometimes nodular; mycelium not separable from the wood blocks as in C 1

P. versipora on *Alnus oregona*, British Columbia (cultures "pinkish buff"; cultures impossible to distinguish by mat features or microscopically from various isolates of *P. subacida*)

P. subacida[5] on *Castanea dentata* ex Division of Forest Pathology, Washington

P. subacida on *Acer circinatum*, British Columbia (cultures "pinkish buff")

[5] All cultures of *Poria subacida* are on the border line with reference to their classification as "water-soaked," and are therefore included in this section.

P. subacida on *Thuja plicata*, British Columbia (cultures "pinkish buff")
P. subacida on *Tsuga heterophylla*, Washington (cultures "pinkish buff") (Pl. III)
P. xantha crassa, "A," Mt. McKinley National Park, Alaska (cultures "pinkish buff"; petri-dish cultures usually more yellowish when young than are those of *P. subacida*)
Unknown Poria ex University of Idaho V. I. F. P. 721 IX 14.40 (culture white)

D. Mycelium in one-year-old red-gum block cultures forming a smooth mat (as in a painted surface), uniform in texture and color, that completely masks the wood from view

P. eupora on *Quercus borealis maxima*, Michigan

D. Mycelium in one-year-old red-gum block cultures not forming a smooth uniform mat (as in a painted surface) ..... E

E. Mycelium in one-year-old red-gum block cultures forming nodules that produce regular tubes and the nodules and tubes appearing flesh-colored

P. vaporaria (?) W. D. 28, ex Canadian Forest Products Laboratory (identification not certain since fungus has not yet been compared with Swedish cultures)

E. Mycelium in one-year-old red-gum block cultures not forming flesh-colored nodules that produce pores; or, if nodules and pores are formed, the nodules are brownish or some other color typical of mycelium in cultures of this age

P. xantha crassa ex Canadian Forest Products Laboratory, 349–3–Q, Canada (pore formation common; mycelium in petri-dish tests for all isolates appearing as a smooth mat over agar at 30° C.)
P. xantha crassa on *Salix interior*, Providence, Northwest Territories (no pore formation)
P. xantha on *Pinus palustris*, Florida (no pore formation)
P. xantha crassa U. 34 on *Picea glauca*, Fort Wrigley, Northwest Territories (no pore formation)
P. xantha crassa "A," Mt. McKinley National Park, Alaska (pore formation)
T. serialis on *Tsuga heterophylla*, Sitka, Alaska (no pore formation;

culture often displaying some brown as a result of drying on wood in cultures of this age; mycelium in petri-dish tests appearing somewhat flaky at 30° C.)

Unknown Poria, ex University of Idaho V. I. F. P. 721 IX 14.40

P. aneirina U. 32 on *Populus tremuloides*, Fort Wrigley, Northwest Territories (Pl. III) (blocks covered by thin mat of mycelium; most of wood visible from beneath mycelium, rhizomorphic; mycelium in petri-dish tests appearing arachnoid in all isolates at 30° C.)

P. aneirina U. 33 on *Populus balsamifera*, Burnt Island, Great Slave Lake, Northwest Territories (Pl. III) (blocks covered by thin mat of mycelium; most of wood visible from beneath mycelium, rhizomorphic)

P. aneirina U. 41 on *Populus balsamifera*, Russian River, Alaska (Pl. III) (blocks covered by only thin mat of mycelium)

P. mollusca on *Acer floridanum*, Florida (Pl. IV) (conspicuous rhizomorphs present on wood; mycelium in petri-dish tests appearing somewhat powdery, but oidia present at 30° C.)

P. corticola on *Populus tremuloides* (thin smooth mat of mycelium covering the blocks in cultures of this age; mycelium in petri-dish tests appearing powdery at 30° C.) (Pl. V)

P. vaporaria sensu Burt non Swedish concept (culture exhibiting practically no aërial mycelium in two-week-old petri-dish cultures, but submerged and appressed mycelium fills dish at 25° and 30° C.)

13. Mycelium more granular or powdery in appearance than arachnoid, i.e. fine threadlike strands not extending out from inoculum at 30° C.; culture always showing aërial mycelium 25

14. Mycelium snow white at 30° C. 15

14. Mycelium "light buff" or "avellaneous" or pinkish as well as white at 30° C. in two-week-old cultures 16

15. Mycelium exhibiting a radiating type of growth at 30° or 25° C. in two-week-old cultures

A. Mycelium in one-year-old red-gum block cultures growing so luxuriantly that the shape of the blocks is completely masked; mycelium as much brown (i.e. "snuff brown") in culture as white and giving the entire culture a brown appearance; black-line formation present

P. sitchensis on *Picea sitchensis*, Sitka, Alaska

A. Mycelium in one-year-old red-gum block cultures not growing so luxuriantly that the shape of the test pieces is masked from view; mycelium white or "avellaneous," but not brown to the extent that much of the culture appears "snuff brown"; no black-line formation ..... B

B. Mycelium in one-year-old red-gum block cultures forming a smooth mat (as in a glossy surface) on the test pieces

T. serpens on *Carpinus sp.*, Florida (see 8 A in key)

B. Mycelium in one-year-old red-gum block cultures flocculent or rhizomorphic, not forming a mat that is smooth as a glossy surface

P. aneirina U. 32 on *Populus tremuloides*, Fort Wrigley, Northwest Territories (Pl. III)

P. aneirina U. 33 on *Populus balsamifera*, Burnt Island, Great Slave Lake, Northwest Territories (Pl. III)

P. aneirina U. 41 on *Populus balsamifera*, Russian River, Alaska (Pl. III)

15. Mycelium having a uniform type of growth, i.e. not radiating at 30° or 25° C. in two-week-old cultures

A. Mycelium in one-year-old red-gum block cultures showing pink fruiting structures, often nodular

F. subroseus on *Larix laricina*, Michigan

A. Mycelium in one-year-old red-gum block cultures not showing pink fruiting nodules; if present, not pink ..... B

B. Mycelium in one-year-old red-gum block cultures showing much dark brown, i.e. "bister," "Verona brown," or "Mars brown"

P. nigra ex Division of Forest Pathology, Washington, 71099 [6] on *Quercus velutina*, Illinois

P. nigra ex Division of Forest Pathology, Washington, 71073 [6]

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[6] *Poria nigra* does not properly belong to the white group of porias, and even old cultures may appear distinctly brown. Often, however, cultures are light, so that there is a possibility of confusing them with other fungi that are "avellaneous," and hence *Poria nigra* is listed in this key. One isolate of *P. nigra* 71118, however, does not fall in this section of the key because of color distinctions.

B. Mycelium in one-year-old red-gum block cultures white or "avellaneous," but not showing dark brown C

C. Mycelium in one-year-old red-gum cultures separating from the wood in fleecelike masses when the flask is shaken

F. pinicola on *Populus balsamifera*, Michigan (culture more "avellaneous" than pinkish)

C. Mycelium in one-year-old red-gum cultures not separating from the wood when the flask is shaken ..... D

D. Mycelium in one-year-old red-gum cultures growing so luxuriantly that three fourths or more of the entire flask is filled with fungous tissue; mycelium conspicuously nodular

F. fraxinophilus on *Fraxinus americana*, Michigan

D. Mycelium in one-year-old red-gum cultures not growing so luxuriantly that most of the flask is filled with fungous tissue; mycelium not nodular or, if nodular at all, inconspicuously so ..... E

E. Mycelium in one-year-old red-gum cultures completely covering the blocks with a thick woolly mat that masks the edges, i.e. edges of wood rounded with mycelial growth ..... F

E. Mycelium in one-year-old red-gum cultures covering or not covering the wood, but never enveloping the block in a thick woolly mat; the edges of the test piece remaining distinct ..... G

F. Mycelium "pinkish buff" in one-year-old red-gum block cultures

P. subacida on *Thuja plicata*, British Columbia (hyphae hyaline in all isolates)

P. subacida on *Tsuga heterophylla*, Washington

P. subacida on *Castanea dentata* ex Division of Forest Pathology, Washington

P. subacida on *Acer circinatum*, British Columbia

P. versipora on *Alnus oregona*, British Columbia (hyphae hyaline)

P. nigra ex Division of Forest Pathology, Washington, 71118 (hyphae with both hyaline and brown walls)

F. Mycelium white in one-year-old red-gum block cultures

P. subacida (?), "white cedar fungus" on *Thuja occidentalis*, Michigan

G. Mycelium in one-year-old red-gum block cultures uniformly "pinkish buff"

P. nigra ex Division of Forest Pathology, Washington, 71118

G. Mycelium in one-year-old red-gum block cultures not uniformly "pinkish buff"; if "avellaneous" or some other related color, color not uniform throughout culture on wood and agar ..... H

H. Mycelium in one-year-old red-gum block cultures forming a uniformly smooth mat over the wood, the mat not flocculent, not granular, and not conspicuously rhizomorphic, but smooth as in a glossy surface

P. undata on *Fraxinus nigra*, Michigan (culture mostly snow white; secondary spores produced) (Pl. IV)

T. serpens on *Carpinus sp.*, Florida (culture white or turning somewhat brown in patches. The mycelium in cultures of this age is so appressed that it may appear skin-like. Secondary spores not produced. See 8 A in key.)

H. Mycelium in one-year-old red-gum block cultures not forming a uniformly smooth mat as in a glossy surface

P. aneirina U. 32 on *Populus tremuloides*, Fort Wrigley, Northwest Territories (all isolates characteristically showing no growth whatever at 35° C. in petri-dish tests) (Pl. III)

P. aneirina U. 33 on *Populus balsamifera*, Burnt Island, Great Slave Lake (Pl. III)

P. aneirina U. 41 on *Populus balsamifera*, Russian River, Alaska (Pl. III)

P. tacamahacae on *Populus balsamifera*, Waterways, Alberta (growth apparent at 35° C. in petri-dish tests)

P. ambigua (?) on *Nyssa biflora*, Florida

P. mollusca on *Acer floridanum*, Florida (culture at first rhizomorphic but not so later; oidia present; mat thin or flocculent; not chamois-like in petri-dish tests) (Pl. IV)

P. Morganii on *Quercus sp.*, Virginia (culture avellaneous; granular or flocculent, not distinctly rhizomorphic; no secondary spores; mat chamois-like in petri-dish tests) (Pl. IV)

P. vaporaria (?), Switzerland; doubtfully the *P. vaporaria* of Sweden (culture avellaneous, mycelium somewhat powdery; no secondary

spores; mat somewhat flocculent in petri-dish tests)

P. undata on *Fraxinus nigra*, Michigan (blocks covered with thin mat of mycelium; not rhizomorphic or not distinctly so; secondary spores; mat thin at 25° C. in petri-dish tests) (Pl. IV)

16. Mycelium more silky [7] than cottony 26
16. Mycelium more cottony than silky 24

17. Mycelium at 25° C. in two-week-old cultures exhibiting a growth of at least 15 mm. 18
17. Mycelium at 25° C. and not exhibiting a growth of as much as 15 mm. .. 20

18. Agar turning yellowish about inoculum at 30° C. and turning yellowish throughout dish at 25° C.; mycelium faintly brown

Pol. alboluteus on stringers of *Picea sitchensis*, dockyard, Juneau, Alaska

Pol. alboluteus U. 6 on *Picea glauca*, Lower Russian Lake, Alaska

18. Agar not turning yellowish about the inoculum at 30° C. and not changing color at 25° C.; mycelium not faintly brown 19

19. Mycelium appressed, silky, granular, powdery, not cottony at 25° C. in two-week-old petri-dish cultures

A. Mycelium in one-year-old red-gum block cultures mostly uniform "cream color" or "cream buff" ..... B
A. Mycelium in one-year-old red-gum block cultures "avellaneous" or some other color, but not uniformly "cream color" or "cream buff" C

B. Mycelium in one-year-old red-gum block cultures forming a mat that completely masks the wood from view

Poria species B (unknown), Mt. McKinley National Park, Alaska

B. Mycelium in one-year-old red-gum block cultures not masking the wood, i.e. wood not at all covered by the fungus

P. mollusca, substratum unknown, Florida (Pl. IV)

C. One-year-old red-gum block cultures exhibiting pore formation

T. alaskana on *Tsuga heterophylla* Lost Lake Trail, Seward, Alaska

T. alaskana U. 43 on *Picea sitchensis*, Kodiak, Alaska

T. alaskana U. 47 on No. 3 common Sitka spruce stringers in mill yard, Juneau, Alaska (this isolate defi-

[7] Where comparative features are described the plants are listed in two different sections of the key.

nitely more cottony in petri-dish tests than all the other isolates of *T. alaskana*)

C. One-year-old red-gum block cultures not exhibiting pore formation .. D

D. Mycelium not covering red-gum blocks in one-year-old cultures

T. heteromorpha U. 10 on *Picea sitchensis*, Juneau, Alaska

T. heteromorpha U. 44 on *Tsuga Mertensiana*, Hope, Alaska

Unknown Poria 25 W. on *Tsuga heterophylla* (check name for *T. alaskana*, *T. sitchensis*, and *T. serialis*), Wrangel, Alaska (oidia present)

Unknown Poria 28 W. on *Tsuga heterophylla*, Wrangel, Alaska

P. mollusca on *Acer floridanum*, Florida (oidia present) (Pl. IV)

P. xantha crassa (?) on *Pseudotsuga taxifolia*, Oregon. (This fungus, unlike other isolates, produces a somewhat uneven white granular to arachnoid mat in petri dishes.)

D. Mycelium covering red-gum blocks in one-year-old cultures ..... E

E. Culture "clay color" as well as white; red-gum blocks collapsing as a result of decay so that they are no longer square in cross section

T. isabellina 6 W. on *Picea glauca*, Selkirk, Yukon Territory

T. isabellina 10 W. on *Picea glauca*, Selkirk, Yukon Territory

E. Culture not "clay color"; red-gum blocks not collapsing as a result of decay so that they are no longer square in cross section

P. xantha crassa (?) on *Pseudotsuga taxifolia*, Oregon (see note for isolate under D)

P. mollusca on *Acer floridanum*, Florida (oidia present) (Pl. IV)

P. corticola on *Populus tremuloides*, Michigan (mycelial mat in petri-dish cultures granular) (Pl. V)

P. crustulina on *Picea glauca*, Tanana, Alaska (mycelium in petri-dish cultures cottony)

T. serialis, *Tsuga heterophylla*, Sitka, Alaska (mycelium in petri-dish cultures flaky)

19. Mycelium not appressed, not silky, not granular, but cottony 23

20. Submerged mycelium showing hyphal swellings at 30° C. in two-week-old cultures

A. Cultures exhibiting "clay color" as well as white in one-year-old red-gum cultures; blocks collapsing within period because of decay so that they are no longer square in cross section

T. isabellina 6 W. on *Picea glauca*, Selkirk, Yukon Territory

T. isabellina 10 W. on *Picea glauca*, Selkirk, Yukon Territory

A. Cultures not exhibiting "clay color" as well as white in one-year-old red-gum cultures; blocks not collapsing within period because of decay so that they are no longer square in cross section

T. variiformis on *Picea glauca*, Michigan (mats of all isolates more or less cerebriform in petri-dish cultures)

T. variiformis on *Picea sp.*, Toklat, Alaska

T. alaskana U. 43 on *Picea sitchensis*, Kodiak, Alaska (mats not cerebriform in petri-dish cultures)

20. Submerged mycelium not exhibiting hyphal swellings at 30° C. in two-week-old cultures 21

21. Mycelium showing a growth of at least 5 mm. at 25° C.

A. Cultures exhibiting "clay color" as well as white in one-year-old red-gum cultures; blocks collapsing within period because of decay so that they are no longer square in cross section

T. isabellina 6 W. on *Picea glauca*, Selkirk, Yukon Territory

T. isabellina 10 W. on *Picea glauca*, Selkirk, Yukon Territory

A. Cultures not exhibiting "clay color" as well as white in one-year-old red-gum cultures; blocks not collapsing within period because of decay so that they are no longer square in cross section ..... B

B. Mycelium in one-year-old red-gum cultures forming a thin white mat over the surface of the wood C

B. Mycelium in one-year-old red-gum cultures not covering the surface of the wood blocks

T. heteromorpha U. 10 on *Picea sitchensis*, Juneau, Alaska

T. heteromorpha U. 44 on *Tsuga Mertensiana*, Hope, Alaska

Unknown Poria 25 W. on *Tsuga heterophylla*, Wrangel, Alaska (oidia present)

Unknown Poria 28 W. on *Tsuga heterophylla*, Wrangel, Alaska

C. Mycelium in one-year-old red-gum cultures distinctly rhizomorphic and not uniformly smooth over the entire surface of the wood

P. crustulina on *Picea glauca*, Tanana, Alaska

C. Mycelium in one-year-old red-gum block cultures not distinctly rhizomorphic, but forming a uniformly smooth mat over the surface of the wood

Unknown Poria F. P. L. 2503 on Cupressus

21. Mycelium not showing a growth of at least 10 mm. at 25° C. in two-week-old cultures in petri dishes

Polystictus abietinus on *Picea glauca*, Healy, Alaska

22. Mycelium "avellaneous" or pinkish on inoculum in two-week-old cultures and frequently growing on the surface of the agar at 35°, 30°, or 25° C. as well

A. Mycelium in six-month-old [8] red-gum block cultures filling flask so that the test pieces are completely masked from view

P. rufa on *Picea glauca*, Fort Wrigley, Northwest Territories

Unknown Poria on *Pinus ponderosa*, locality unknown

Unknown Poria on *Taxodium distichum* railroad ties, Georgia

A. Mycelium in six-month-old red-gum block cultures not filling flask so that the test pieces are completely masked from view

T. rigida on *Quercus Shumardii*, Florida

22. Mycelium not "avellaneous" but white on the inoculum in two-week-old petri-dish cultures, as well as on the surface of the agar at 35°, 30°, or 20° C.

A. Mycelium in one-year-old red-gum block cultures growing so luxuriantly that the shape of the test pieces is masked from view .... B

A. Mycelium in one-year-old red-gum block cultures not growing so luxuriantly that the shape of the test pieces is masked from view

P. lenis on *Juniperus virginiana*, Maryland (Pl. V)

Unknown Poria U. 23 on Gowan's cypress, California

B. Mycelium in one-year-old red-gum block cultures exhibiting "fawn color" and tendency to red line formation

P. tinctipora (?) on *Liquidambar styraciflua*, Georgia (Pl. V)

B. Mycelium in one-year-old red-gum block cultures white, whitish, or exhibiting patches of red brown or some color other than "fawn color" C

C. Mycelium in one-year-old red-gum block cultures exhibiting red-brown patches

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[8] The fungus *T. rigida* Fries can be distinguished readily from the *Poria rufa* group by its growth in six-month-old red-gum block cultures, but not by the standard one-year-old cultures used generally throughout the key.

T. serialis from mill-roof timber, Rhode Island. (This isolate has been classified (5) under the name *Polyporus palustris* B. & C.)

C. Mycelium in one-year-old red-gum block cultures white to "avellaneous," but not exhibiting red-brown patches

P. lenis on *Juniperus virginiana*, Maryland

23. Mycelium exhibiting a growth of only approximately 10 mm., often less, at 30° C.

A. Mycelium in one-year-old red-gum block cultures "clay brown" as well as white; blocks collapsing because of decay so that their shape is no longer square in cross section

T. isabellina 10 W. on *Picea glauca*, Selkirk, Yukon Territory

T. isabellina 6 W. on *Picea glauca*, Selkirk, Yukon Territory

A. Mycelium in one-year-old red-gum block cultures not "clay brown" as well as white; blocks not collapsing because of decay ..... B

B. One-year-old red-gum block cultures exhibiting pore formation

T. alaskana U. 43 on *Picea sitchensis*, Kodiak, Alaska (in petri-dish tests fungus growing approximately 10 mm. at 30° C. in two weeks)

T. alaskana U. 47 on stringers and caps, Juneau, Alaska (in petri-dish tests fungus growing approximately 10 mm. in two weeks)

B. One-year-old red-gum block cultures not exhibiting pore formation

T. heteromorpha U. 10 on *Picea sitchensis*, Juneau, Alaska (growing more slowly than *T. alaskana* in two-week-old petri-dish cultures; i.e. it exhibits only 1 mm. growth at 30° C.)

T. heteromorpha U. 44 on *Tsuga Mertensiana*, Hope, Alaska (growing somewhat more slowly than *T. alaskana* in two-week-old petri-dish cultures; i.e. it grows approximately 4 mm. at 30° C.)

23. Mycelium exhibiting a growth of approximately 20 mm., often more, at 30° C. in two-week-old cultures

A. Red-gum wood blocks collapsing in one-year-old cultures so that they are no longer square in cross section; mycelium forming a white network of strands over the wood

P. ferruginosa on *Thuja occidentalis*, Minnesota

A. Red-gum blocks not collapsing in one-year-old cultures so that they no longer appear square in cross section; mycelium not forming a white network of strands over the wood ..... B

B. Mycelium distinctly more "avellaneous" or cream color than white in one-year-old red-gum block cultures and forming a smooth and uniform mat over the surface of the wood

T. malicola on *Populus grandidentata*, Michigan (mat somewhat chamois-like in petri-dish tests) (Pl. V)

P. corticola on *Populus tremuloides*, Michigan (mat granular or powdery in petri-dish tests) (Pl. V)

P. mollusca (substratum unknown), Florida (mat flocculent in petri-dish tests) (Pl. IV)

B. Mycelium white or at least more whitish than "avellaneous" in one-year-old red-gum block cultures

P. mollusca on *Acer floridanum*, Florida (oidia present) (Pl. IV)

P. alaskana on *Tsuga heterophylla*, Seward, Alaska (growing faster than other isolates of the species; i.e. it grows only 10 mm. or less at 30° C. in two weeks)

24. Mycelium pink as well as white in two-week-old petri-dish cultures ... 27

24. Mycelium white, not pink in two-week-old petri-dish cultures

A. One-year-old red-gum block cultures exhibiting pink nodular fruiting structures; mycelium also showing pink

F. subroseus on *Larix laricina*, Michigan

A. One-year-old red-gum block cultures not exhibiting pink nodular fruiting structures; mycelium not showing pink ..... B

B. Mycelium chocolate brown, i.e. "bister," as well as white

P. nigra ex Division of Forest Pathology, Washington, 71099 on *Quercus velutina*, Illinois

B. Mycelium not chocolate brown at all, but white or "avellaneous"

P. mollusca on *Acer floridanum*, Florida (Pl. IV)

25. Mycelium pinkish at 30° C. in two-week-old petri-dish cultures

P. purpurea on *Pinus contorta*, Jasper, Alberta

25. Mycelium not pinkish at 30° C. in two-week-old petri-dish cultures

A. Mycelium in one-year-old red-gum block cultures distinctly "avellaneous," i.e. more "avellaneous" than white

P. corticola on *Populus tremuloides*, Michigan (Pl. V)

A. Mycelium in one-year-old red-gum block cultures; more of it white than "avellaneous"

P. mollusca on *Acer floridanum*, Florida (oidia present) (Pl. IV)

26. Mycelium pinkish in two-week-old petri-dish cultures

A. Blocks in one-year-old red-gum cultures collapsing so that the test pieces are no longer square in cross section

P. semitincta on *Quercus marilandica*, North Carolina

A. Blocks in one-year-old red-gum cultures not collapsing

P. purpurea on *Pinus contorta*, Jasper, Alberta

26. Mycelium not pinkish in two-week-old petri-dish cultures

A. Mycelium in one-year-old red-gum block cultures pinkish, i.e. "fawn color"

P. semitincta on *Quercus marilandica*, North Carolina

A. Mycelium in one-year-old red-gum block cultures not pinkish

P. aneirina U. 32 on *Populus tremuloides*, Fort Wrigley, Northwest Territories (Pl. III)

P. aneirina U. 33 on *Populus balsamifera*, Burnt Island, Great Slave Lake, Northwest Territories (Pl. III)

P. aneirina U. 41 on *Populus balsamifera*, Russian River, Alaska (Pl. III)

27. Mycelium exhibiting a cerebriform type of growth at 25° C. in two-week-old petri-dish cultures

P. purpurea on *Pinus contorta*, Jasper, Alberta

27. Mycelium not exhibiting a cerebriform type of growth at 25° C.

A. Pink nodular fructifications appearing in one-year-old red-gum block cultures

F. subroseus on *Larix laricina*, Michigan

A. Pink nodular fructifications not appearing in one-year-old red-gum block cultures

Unknown Poria on western yellow pine, locality unknown

Unknown Poria on *Taxodium distichum* railroad ties, Georgia

University of Michigan

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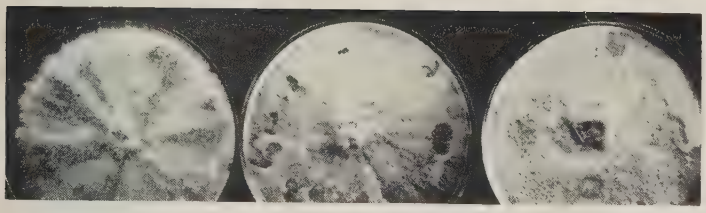
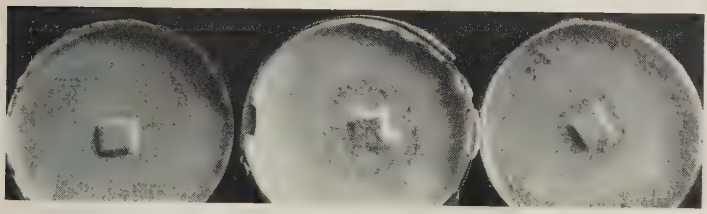
5. Nobles, M. K. 1943. A Contribution toward a Classification of the *Trametes serialis* Complex. Can. Journ. Res., 21 : 211–234.

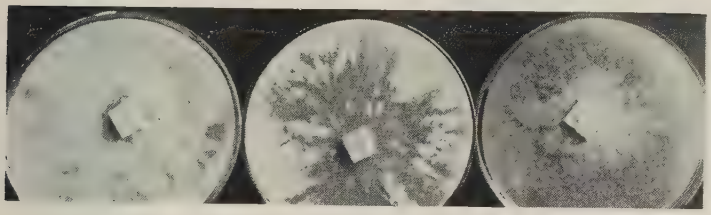
PLATES I–VI



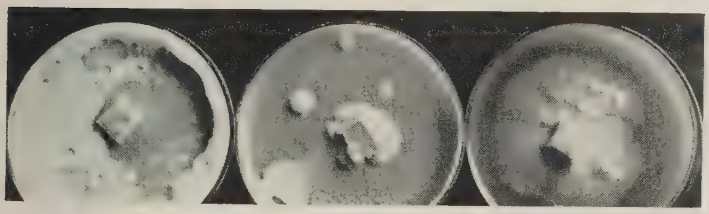
Trametes rigida on *Quercus Shumardii*, from Florida



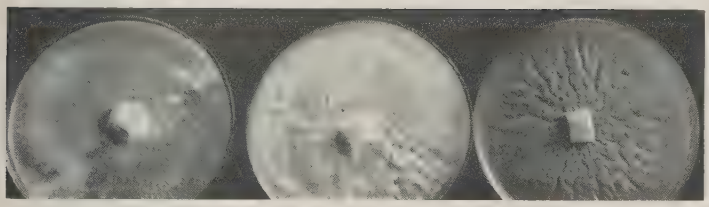
Poria unita on *Quercus sp.*, from Michigan



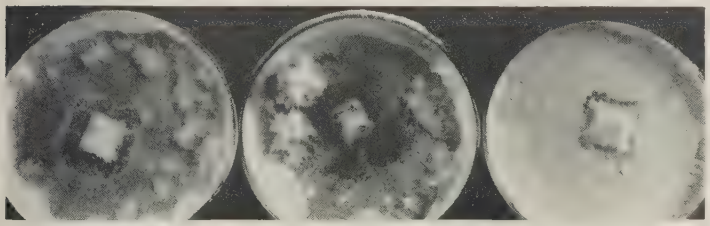
Poria albipellucida on *Tsuga heterophylla*, from Washington



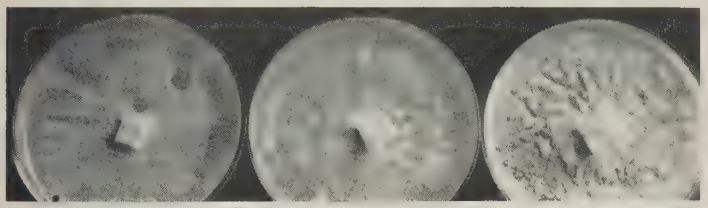
Poria tacamahacae on *Populus balsamifera*, from Waterways, Alberta



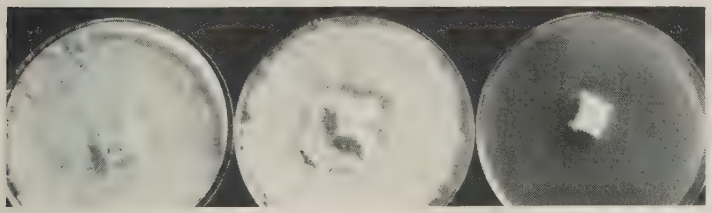
Poria subfusco-flavida on *Pseudotsuga taxifolia*; locality unknown



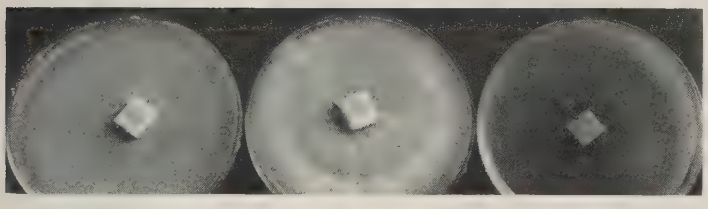
Polyporus anceps on *Picea glauca*, from Fort Wrigley, Northwest Territories



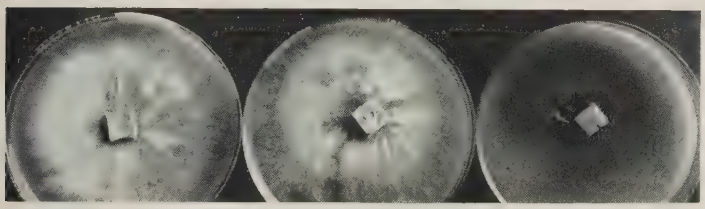
Poria albobrunnea on *Pinus caribaea*, from Georgia



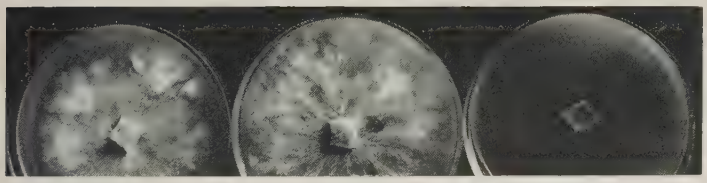
Poria incrassata, ex United States Forest Products Laboratory, Madison, Wisconsin



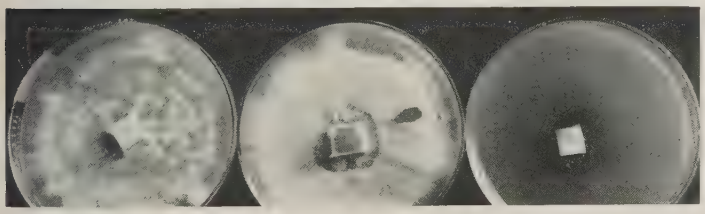
Poria subacida on *Tsuga heterophylla*, from Washington



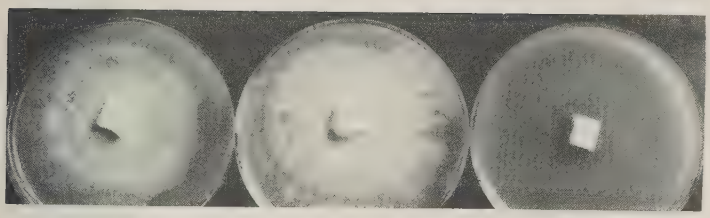
Poria aneirina U. 32 on *Populus tremuloides*, from Fort Wrigley, Northwest Territories



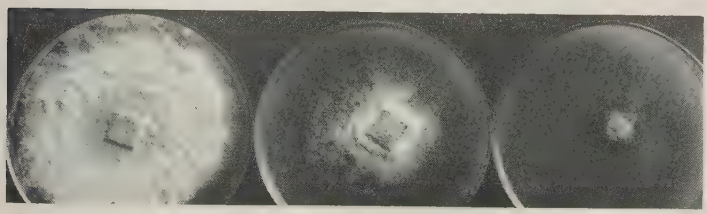
Poria aneirina U. 33 on *Populus balsamifera*, from Fort Wrigley, Northwest Territories



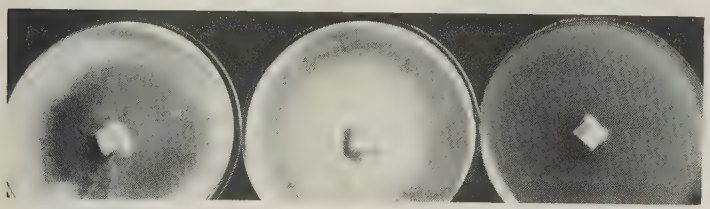
Poria aneirina U. 41 on *Populus balsamifera*, from Russian River, Alaska



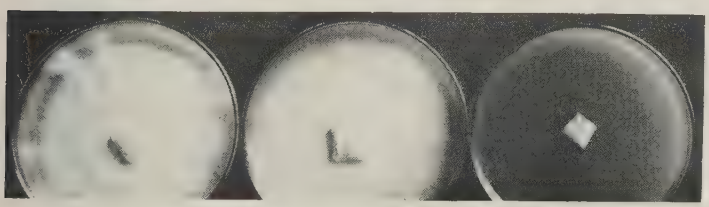
Poria mollusca on *Acer floridanum*, from Florida



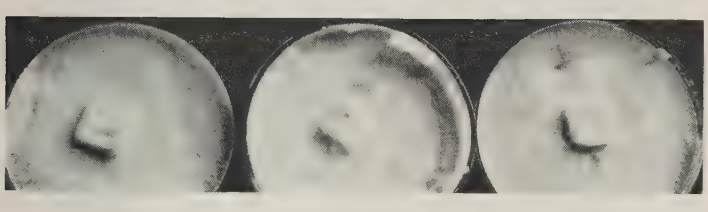
Poria mollusca, substratum unknown, from Florida



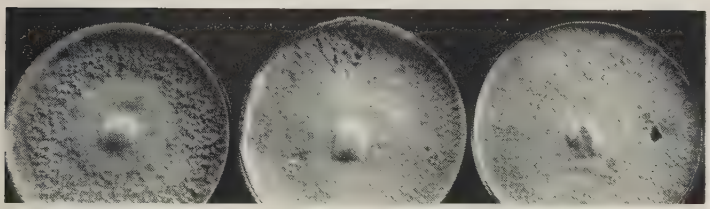
Poria undata on *Fraxinus nigra*, from Michigan



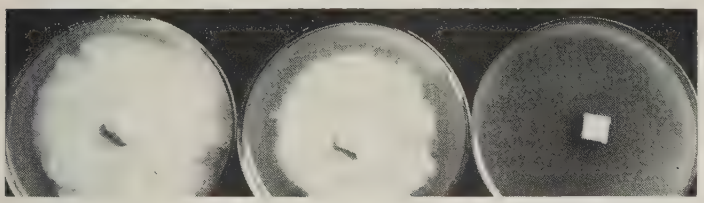
Trametes Morganii on *Quercus sp.*, from Virginia



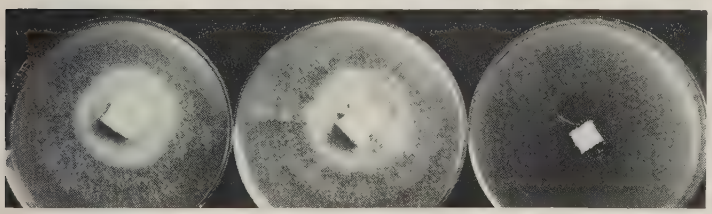
Poria lenis on *Juniperus virginiana*, from Maryland



Poria tinctipora (?) on *Liquidambar styraciflua*, from Georgia



Trametes malicola on *Populus grandidentata*, from Michigan



Poria corticola on *Populus tremuloides*, from Michigan

One of five cases of cultures that constitute a part of the reference collection of North American polypores at the School of Forestry and Conservation, University of Michigan. The fungi, which were collected on many types of substrata in various parts of the continent, are cultured on red-gum test pieces and duplicated on white-pine blocks

SHADE METHOD OF DIRECT CAMBIUM-TO-BARK DEVELOPMENT

CARL GEORGE FENNER

THE healing of bark-deep wounds upon which the cambium is undisturbed has always been a matter of great interest to tree scientists, park men, tree workers, and owners of fruit and shade trees. Many are the stories (some true and some false) concerning the success of the tree "doctor" in healing and saving completely girdled trees by the use of cow dung. Some twenty years ago I saw an old gardener treat and bring to complete recovery a fine but tender ten-inch white birch by means of this material. This observation inspired a search for a wound covering that would be easier and more pleasant to handle, and perhaps as efficient. Over a period of ten years many coverings of soft sterile materials were tried without encouraging results. Failure appeared to be due to the impossibility of preventing various parasitic fungi from destroying the sensitive exposed cambium cells. All coverings tested actually protected and favored the growth of these fungi rather than that of the cambium.

During the treatment and subsequent observation of hundreds of wounds caused by motor vehicles, horses, dogs, children, and other agencies it was often found that small bark-deep injuries on the north or shaded side of the trunk developed healthy bark directly from cambium when no covering or dressing was applied. Subsequently it was noted that the cambium on areas on the sunny side of tree trunks dried out and died when left exposed. Apparently the drying effect of direct sun rays was the cause of death. Attempts to prove this theory gave birth to the idea of shading by artificial means all bark-deep wounds. It was found that the cambium cells could be protected and saved from desiccation by the erection of a burlap barrier or shade. The shading material is held on steel or wooden frames, which usually form an enclosure about the trunk. Wrapping fails to allow sufficient air circulation. In fact, it became necessary